Investigation of Subterranean Fuel Vapor Extraction and Destruction Using a Diesel Engine: Phase II

INTERIM REPORT
TFLRF No. 366

by
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for
U.S. Air Force Center for Environmental Excellence
Installation Excellence Worldwide Directorate
Brooks City-Base
San Antonio, TX

Under Contract to
U.S. Army TARDEC
Petroleum and Water Business Area
Warren, MI

Contract No. DAAE-07-99-C-L053

June 2003

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Approved by:

Edwin C. Owens, Director
U.S. Army TARDEC Fuels and Lubricants
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13. ABSTRACT (Maximum 200 words)
This project aims to remediate fuel spills by extracting hydrocarbon vapors from contaminated earth, and burning them in a diesel engine. The diesel engine destroys hydrocarbons more effectively than spark-ignited units currently in use, uses less fuel, and uses fuel commonly available on Air Force installations. A surplus diesel-powered air compressor was fitted with a torque measurement device and other measurement and control mechanisms for the project. The torque sensor's data was correlated to previously acquired data, with blower pressure used to gauge engine load. Testing using three different hydrocarbon gases in various concentrations to simulate well gases, at a variety of engine speed and load conditions, investigated how the engine would behave in actual use. Limitations were identified in terms of the concentration of gaseous fuel, hydrocarbon destruction efficiency and the fuel required. Further testing with intake air throttled, to simulate the pumping work the engine will have to perform when attached to a well, showed that the engine will run safely and continue to effectively destroy hydrocarbons so long as sufficient oxygen is inducted, either from the well or from fresh air. Conclusions from these data are presented, and recommendations for future testing are offered.

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EXECUTIVE SUMMARY

Problems and Objectives: Environmental and health hazards posed by soil contamination resulting from underground fuel tank leakage and spillage at U.S. Air Force bases have created a need for cost-effective methods of removing volatile and combustible compounds from subterranean soil. Following removal of as much liquid-state contaminant as possible from a site, the next step in the clean-up process is further removal of contaminant in gaseous form as it evaporates from the saturated soil. One method employed is to bore a well, insert a pipe into the contaminated soil and route the vapors into the intake of a running engine for combustion.

Current engines used for this task are spark-ignited automotive models using propane or natural gas as supplemental fuel during startup and lean vapor conditions. The purpose of this project is to investigate whether a compression-ignition (CI) diesel engine could perform the same function, perhaps increasing efficiency, durability and reliability.

Importance of Project: Continuous operation of an engine for this purpose can result in significant maintenance cost over time. The inherently sturdier design of compression-ignition engines predicts greater durability and a longer life cycle between rebuilds. Other important advantages that a CI engine may offer in this application are the capability to operate at leaner air-fuel ratios and the ability to use readily available JP-8 as a supplemental fuel instead of bottled gases. Using a liquid fuel could also reduce the requirement for refueling, since a larger tank could be used, thereby reducing the associated labor costs.

Technical Approach: A small diesel engine obtained from Air Force surplus inventory was equipped for operation as a pre-mixed vapor dual-fuel test platform. Propane, butane and pentane in various concentrations were used as surrogate gases to simulate fuel vapors found in a typical well site. The engine was operated at various steady state speed and load conditions while the gas to air ratio in the intake air stream was incrementally increased. At each test point, the cylinder pressure was monitored for indications of potentially damaging knock, and parameters such as fuel and air consumption rates and engine temperatures were recorded.

Accomplishments: Data was acquired at a wide range of engine speed and load conditions, using different concentrations of the hydrocarbon gases, to investigate and describe how the engine will operate in actual use at a well site. Further testing examined how the engine would operate with the intake throttled, to simulate the pumping work required to extract the gases from a well. The operating conditions were defined, in preparation for a field test in the following project phase.

Military Impact: The results of this limited study show promise for the possibility of using diesel engines in the task of removing and destroying fuel vapors from underground contamination sites. If the concept ultimately proves practicable through further investigation, it could potentially increase the effectiveness and reliability of engine-based ground vapor removal systems while simultaneously reducing the maintenance costs associated with them.

FOREWORD/ACKNOWLEDGMENTS

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ACRONYMS & ABBREVIATIONS

AFCEE	U. S. Air Force Center for Environmental Excellence
bhp	Brake Horsepower
CI	Compression Ignition
CO	Carbon Monoxide
CO_2	Carbon Dioxide
ERT	Environmnental Restoration Team
ft-lb$_f$	Foot-pound(s) (force)
GC	Gas Chromatograph
HC	Hydrocarbons(s)
kPaa	Kilopascals (absolute)
lbm	Pound mass
LFE	Laminar Flow Element
ppt	parts per thousand
psig	Pound(s) per square inch (gauge)
PPM	Parts Per Million
RPM	Rotation(s) per minute
SI	Spark Ignited
SwRI	Southwest Research Institute
TARDEC	Tank-Automotive Research Development and Engineering Center
TACOM	Tank-Automotive Armaments Command
TFLRF	U.S. Army TARDEC Fuels and Lubricants Research Facility
T/p	Torque/pressure
TVH	Total Volatile Hydrocarbons

1.0 BACKGROUND

Over a period of many years, leakage from underground fuel storage tanks and other sources has contaminated the ground soil sites at many US Air Force bases worldwide. The common technique used for cleanup at these locations is to drill into the contaminated soil and extract as much liquid waste as possible. Following removal of the majority of the liquid fuel, the remainder is extracted in vapor form with the aid of an internal combustion engine adapted to burn the vapors as fuel. The extraction unit currently in use has a spark-ignited (SI) automobile engine that serves as both a vapor "pump" and a means of vapor destruction, with propane or natural gas serving as a supplemental fuel during startup and lean conditions.

In order to obtain increased efficiency, durability and reliability in these engine-based extraction units, the Air Force has contracted Southwest Research Institute (SwRI) to investigate the feasibility of using compression-ignition (CI) engines in place of the SI automobile engines now employed. An engine utilized in this role would operate similarly to a dual-fuel natural gas/diesel unit, using distillate fuel as a pilot to ignite the extracted gas charge.

2.0 OBJECTIVES

The initial phase of testing demonstrated that the basic concept of burning pre-mixed gaseous fuel vapors in a diesel engine using liquid fuel as an ignition pilot is indeed feasible. It has been shown that the combustion of a gaseous fuel increases as engine load increases. It was found that under significant loading conditions, the pilot fuel amount can be reduced to approximately 20% of the total fuel requirement, assuming the fuel vapors are of high enough concentration to sustain engine operation.

For reasons of practicality and availability, first phase testing used propane gas as a surrogate to simulate well vapors. With the knowledge gained from that testing, the

second project year seeks to develop the concept using gases that more closely approximate the molecular weight and composition of typical well vapors.

Work performed in Phase II incorporates the following additional items to further determine concept feasibility:

- Measurement of engine load at test points to better facilitate duplication of laboratory conditions in future field experiments.
- Exhaust emissions analysis, including evaluation of hydrocarbons, smoke, CO and CO_2 concentrations.
- Mapping of quantitative gas consumption rates and efficiencies.
- A throttling experiment to examine the effects of engine intake air restriction, as would be seen when installed at a well site.

3.0   EXPERIMENTAL APPROACH

3.1   Setup Modifications

In order to determine the load applied to the engine during testing, a novel torque-sensing instrument was installed in the coupling between the engine and the roots blower. Figure 1 below shows the coupling that was on the cabin pressurization unit when received at SwRI. Figure 2 below shows the torque-sensing coupling installed in its place. Comparing the two views reveals that it was necessary to remount the blower farther from the engine in order to accommodate the additional equipment. Installation of the instrument included design and fabrication of flanges to mate to the flywheel and blower, careful shaft alignment of the components, and integration into the cell's data acquisition system.

Figure 1. Original Coupling
(top view)
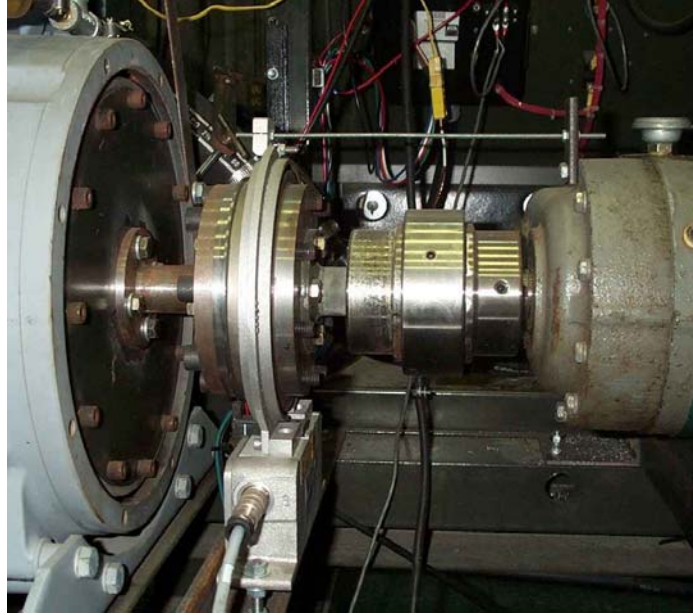
Figure 2. Torque-Sensing Coupling
(side view)

The device is an HBM T10F Flange Torque Sensor. It uses shear stress to measure torque instead of torsional stress. The measurement signal telemetry and the coupling of excitation voltage are carried out inductively via antenna segments that enclose the flange in a ring shape. This makes the instrument compact, and the lack of physical contact allows it to provide very high accuracy.

Figure 3 shows another view of the coupling. In Figure 3, the Roots blower is in the foreground and the flywheel end of the Hatz engine is in the background. The device closest to the flywheel is the torque sensor. The middle portion, out to the maroon-colored ring, rotates within the silver-colored stator. The enclosure below the stator houses the excitation and sensing parts of the instrument. A rod extends from the blower housing to the top of the stator ring, to stabilize the structure (thus the signal) during operation. A coupling to absorb torsional vibrations is in place on the shaft between the torque sensor and the blower.
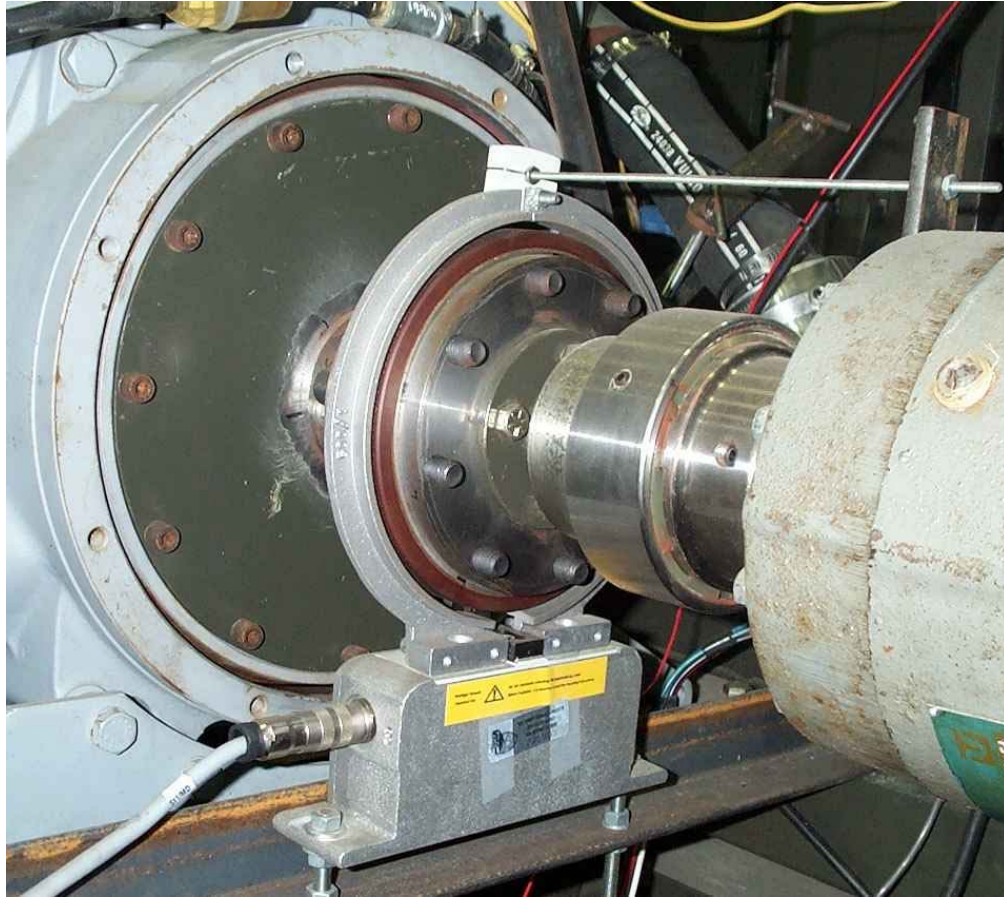
Figure 3. Detail of Torque Sensor

Lacking this torque sensor, the initial testing was performed by setting blower pressures to obtain different levels of load. "Light" load used a setting of 2 psig, "Intermediate" load used 8 psig, and "Heavy" load used 11 psig. To compare these load levels with data taken later, a load curve was measured, correlating blower pressure with engine torque. Figure 4 is a plot of this data. All data was acquired at 2000 rpm.
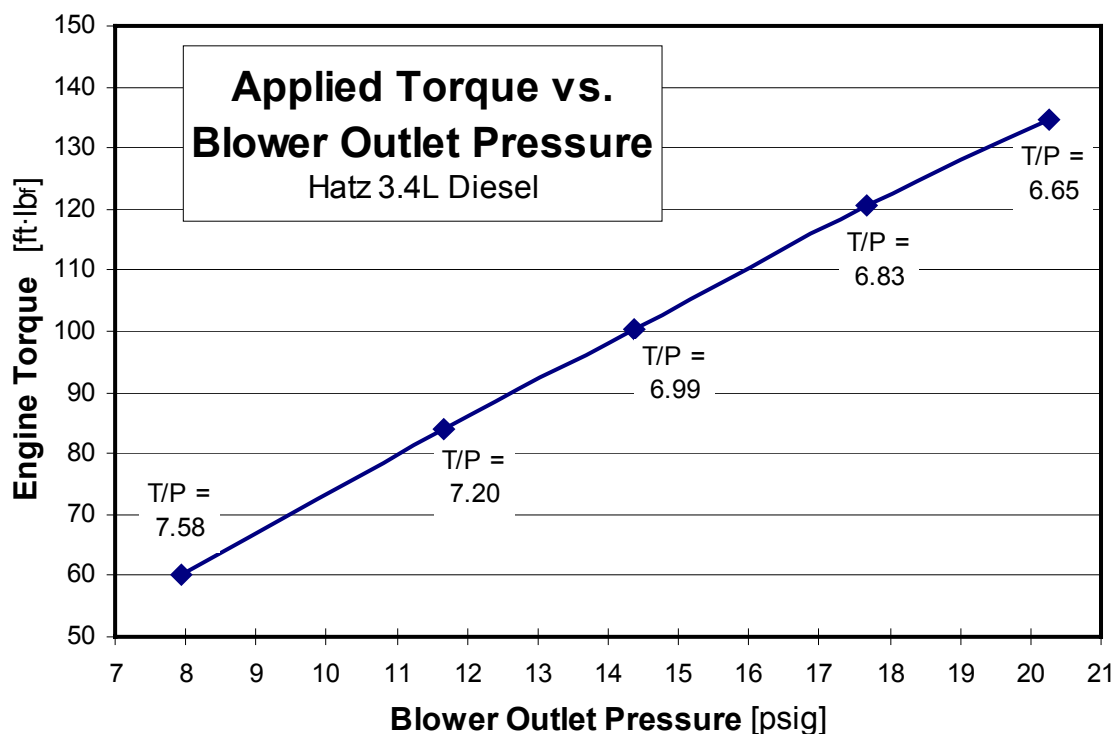
Figure 4. Blower Outlet Pressure correlated to Engine Torque

In order to counteract the low vapor pressure of pentane gas at ambient conditions, a simple water-immersion bottle heater was constructed and installed. This is necessary to provide sufficient in-cylinder vapor pressure to achieve gas flow rates that will allow the desired ratios of gas to liquid fuel to be attained. The pentane tank in the immersion heater is shown in Figure 5. The temperature control for the electric heater is visible at the lower-left of the tank.

For this same purpose, piping carrying the gaseous fuel was wrapped with insulation. Heating wraps were installed on some lines.

Figure 5. Immersion Heater

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The air pressure regulating system of the cabin pressurization unit was removed and replaced with a manually controlled butterfly valve to simplify operation. Controls for engine throttle, gas flow and blower backpressure were relocated to the operator console.

Emissions measuring equipment was installed in the test cell to measure exhaust concentration of hydrocarbons at each test point and condition, as well as hydrocarbon content in the inlet air stream — with or without added gaseous fuel.

3.2   Testing Procedures

Similar to the procedure followed in Phase I, tests were conducted according to a matrix involving variations in engine speed, engine load and pilot fuel percentage to map characteristics at steady-state operating conditions. Performance measurements include a range of pertinent temperatures, pressures, flow rates and engine operating parameters, as well as emissions as previously described.

The testing commenced using propane $[C_3H_8]$ as the surrogate well vapor to establish baseline performance parameters. This strategy was employed because it was anticipated that the lighter hydrocarbons would present the greatest challenge to the feasibility of the concept. The high octane rating, therefore low cetane rating, of the propane was expected to be a problem for a diesel engine. The testing did indicate some limitations on safe engine conditions, but overall proved that the use of a diesel engine for vapor destruction was feasible. Following successful completion of testing using propane, the test matrix was repeated with butane $[C_4H_{10}]$ gas, then with pentane $[C_5H_{12}]$ gas. Progressing by steps higher in carbon number was to provide an indication of how a heavier molecular weight gas affects the combustion characteristics of the engine.

The carbon content of pentane is representative of the majority of hydrocarbons found in the vapor sample extracted at Kelley AFB, and results obtained with pentane should be a good indicator of prospective performance at a well site. Pentane will provide the closest approximation of actual well vapors for laboratory testing.

The engine was tested at four load levels, at 2000 rpm under all conditions. At each load level, data acquisition commenced without gaseous fuel. Gaseous fuel was then introduced, and the JP-8 fuel flow rate correspondingly reduced, until a desired proportional mixture was achieved, at the previously set engine speed and load. Data was acquired, then the procedure was repeated to further reduce the JP-8 fuel proportion of the total fuel. This procedure was repeated until the JP-8 fuel was only 10% of the total, or until misfire, knock or other combustion problem occurred. Finally, the gaseous fuel was shut off and the JP-8 flow returned to the original rate to repeat the initial condition, to ensure that nothing had changed during testing.

With all data acquired for a given load level, this procedure was repeated for the next-higher load until all conditions had been tested. This matrix is summarized in Table 1:

Table 1. Test Conditions

Designation	Engine Speed	Engine Load	JP-8 % of Total
1A1	2000 rpm	60 ft·lb$_f$	100 %
1B	2000 rpm	60 ft·lb$_f$	80 %
1C	2000 rpm	60 ft·lb$_f$	60 %
1D	2000 rpm	60 ft·lb$_f$	40 %
1E	2000 rpm	60 ft·lb$_f$	20 %
1F	2000 rpm	60 ft·lb$_f$	10 %
1A2	2000 rpm	60 ft·lb$_f$	100 %
2A1	2000 rpm	80 ft·lb$_f$	100 %
2B	2000 rpm	80 ft·lb$_f$	80 %
2C	2000 rpm	80 ft·lb$_f$	60 %
2D	2000 rpm	80 ft·lb$_f$	40 %
2E	2000 rpm	80 ft·lb$_f$	20 %
2F	2000 rpm	80 ft·lb$_f$	10 %
2A2	2000 rpm	80 ft·lb$_f$	100 %
3A1	2000 rpm	100 ft·lb$_f$	100 %
3B	2000 rpm	100 ft·lb$_f$	80 %
3C	2000 rpm	100 ft·lb$_f$	60 %
3D	2000 rpm	100 ft·lb$_f$	40 %
3E	2000 rpm	100 ft·lb$_f$	20 %
3F	2000 rpm	100 ft·lb$_f$	10 %
3A2	2000 rpm	100 ft·lb$_f$	100 %
4A1	2000 rpm	120 ft·lb$_f$	100 %
4B	2000 rpm	120 ft·lb$_f$	80 %
4C	2000 rpm	120 ft·lb$_f$	60 %
4D	2000 rpm	120 ft·lb$_f$	40 %
4E	2000 rpm	120 ft·lb$_f$	20 %
4F	2000 rpm	120 ft·lb$_f$	10 %
4A2	2000 rpm	120 ft·lb$_f$	100 %

3.3   Problems Encountered

A malfunctioning fuel shutoff solenoid on the Hatz engine had to be corrected. The solenoid prevented the engine from starting for more than a few seconds at a time. A solution was found to circumvent the problem and allow the engine to run normally, but only after approximately a week of investigation and repair.

Utilization of pentane as a surrogate test gas proved to be a challenge. During testing, an error in dispenser configuration resulted in liquid pentane being introduced into the engine air stream. The surge in available energy caused a very rapid rise in engine speed and cylinder pressure along with likely detonation that destroyed the cylinder pressure transducer. Upon receiving the properly packaged pentane, and installation of another transducer, another attempt was made at running the test matrix. During execution of the test, another problem was encountered with pentane condensing in the supply lines, resulting in a second surge event and a second transducer failure. Following removal of an in-line pressure regulator that was contributing to the condensation problem, and the installation of additional heat tapes, the condensation problem was solved. Testing was then resumed, with the full test matrix being completed on pentane fuel.

Upon start of the engine for the next test session, a pronounced audible knock was detected. Investigation and disassembly showed that the piston and bore of cylinder 1 were damaged. It appears that debris from one of the failed pressure transducers lodged between the piston and cylinder wall resulting in broken rings and a damaged piston. The engine was repaired and a new pressure transducer was installed.

The intake piping as originally installed sloped steeply downward, and the "gas ring" where the gaseous fuel was introduced was very close physically to the engine. This arrangement is shown in Figure 6 on the left below.

Figure 7 on the right shows the new arrangement of the piping. In order to prevent recurrence of this problem, the air intake piping was reconfigured to prevent liquid fuel,

even if it does reach the intake piping, from entering the engine. Bright green lines have been added to the picture to indicate the position of the pipes in places where they are concealed behind the engine or other equipment. Note that the gas ring is now much farther from the engine, and lower than before. Should liquid fuel ever again reach the intake air stream, it would have to flow uphill through nearly two meters of piping, while being evaporated by the inlet air flow, before reaching the engine. The focus will remain on preventing liquid fuel from being introduced at all, but this added safeguard should prevent further engine damage.

Figure 6. Original Setup
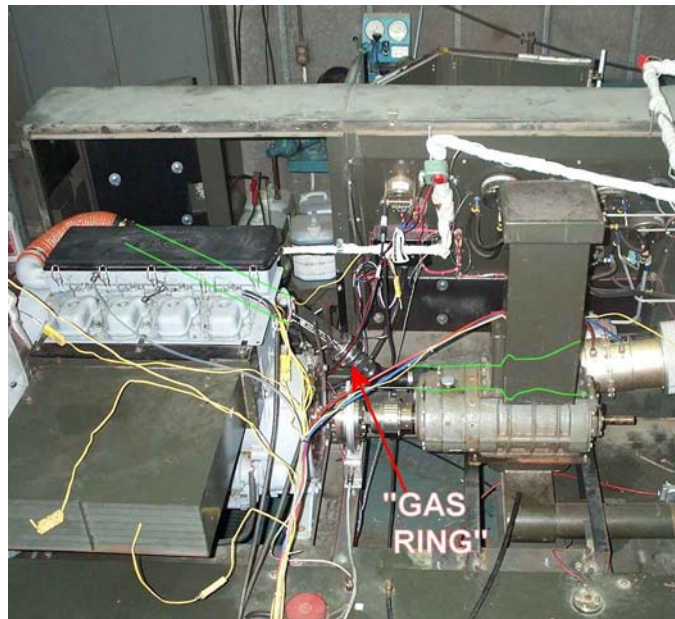
Figure 7. Revised Intake Piping

4.0   RESULTS

A complete set of tabulated test data is attached as Appendix A.   A summary of the pertinent test data for discussion is shown in Table 2. All of this data was acquired using pentane as the gaseous fuel, at an engine speed of 2000 rpm. The shaded rows in Table 2 indicate the test condition for each torque setting which used the highest proportion of gaseous fuel without evidencing audible knock.

As previously noted, the pentane used in these experiments as a well gas surrogate most closely approximates the sample collected at Kelly AFB.   As this data is therefore expected to most closely predict the operation of the unit in actual use at a well site, this analysis will discuss only the results obtained using pentane.

4.1   Upper Limit of Gaseous Fuel Ingestion

The first effect visible in these data is an apparent limit of the gaseous fuel flow rate without inviting knock. In all but the lowest-load data (60 ft·lb$_f$), more than 7 lb$_m$/hr of pentane invited knock.   This exception likely resulted from the lower cylinder temperatures associated with the lower engine load. It should be noted that this inference depends on perceptible monitoring for knock as the cylinder pressure instrumentation was inoperative.

Table 2. Vapor Destruction Data Using Pentane

Test Desig.	Engine Power	Torque	Air Flow LFE Dry	JP-8 Fuel Flow	Gaseous Fuel Flow	Total Fuel Flow	Air / JP-8 Ratio	Air / Gaseous Fuel Ratio	Air / Total Fuel Ratio	BSFC	Exhaust HC	Intake HC	HC Reduction
-	bhp	ft·lb$_f$	lb$_m$/hr	lb$_m$/hr	lb$_m$/hr	lb$_m$/hr				lb$_m$/bhp·hr	ppm	ppm	%
1A1	23.2	61.0	391.69	10.017	0	10.02	39.10	-	39.10	0.431	638	4	
1B	23.2	60.9	388.01	7.893	2.048	9.94	49.16	189.5	39.03	0.428	1591	11194	85.8
1C	23.1	60.8	387.58	6.083	4.033	10.12	63.71	96.1	38.31	0.437	2296	20365	88.7
1B2	23.3	61.1	389.00	8.024	1.938	9.96	48.48	200.8	39.05	0.427	1702	10723	84.1
1D	23.3	61.1	386.38	4.099	6.139	10.24	94.25	62.9	37.74	0.440	2660	30072	91.2
1E	23.1	60.5	383.89	1.825	7.821	9.65	210.30	49.1	39.80	0.418	2751	37461	92.7
1A2	23.2	60.8	387.79	9.982	0	9.98	38.85	-	38.85	0.431	697	5	
2A1	30.6	80.3	385.01	12.181	0	12.18	31.61	-	31.61	0.398	668	2	
2B	30.5	80.0	383.12	9.531	2.394	11.93	40.20	160.0	32.13	0.391	1471	12918	88.6
2C	30.2	79.5	380.98	7.136	4.717	11.85	53.39	80.8	32.14	0.392	1913	24038	92.0
2D	30.6	80.1	379.51	4.791	7.062	11.85	79.21	53.7	32.02	0.388	2335	35343	93.4
2E	29.6	77.7	345.46	3.259	11.520	14.78	106.01	30.0	23.37	0.499	1117	56357	98.0
2A2	30.7	80.4	378.67	12.316	0	12.32	30.75	-	30.75	0.402	678	3	
3A1	38.5	100.9	376.86	15.024	0	15.02	25.08	-	25.08	0.391	667	2	
3B	38.1	99.8	375.17	11.350	2.920	14.27	33.06	128.5	26.29	0.375	1402	17297	91.9
3C	39.0	102.3	372.56	8.919	5.763	14.68	41.77	64.7	25.38	0.376	1566	30193	94.8
3D	37.9	99.3	350.89	6.548	9.668	16.22	53.59	36.3	21.64	0.428	668	51027	98.7
3C+	38.5	100.9	363.03	7.011	7.556	14.57	51.78	48.1	24.92	0.379	1036	39954	97.4
3A2	39.0	102.4	371.59	15.301	0	15.30	24.28	-	24.28	0.392	785	1	
4A1	45.6	119.6	371.07	17.948	0	17.95	20.67	-	20.67	0.393	501	1	
4B	45.8	120.0	370.28	13.203	3.637	16.84	28.05	101.8	21.99	0.368	1330	20670	93.6
4C	45.9	120.4	360.46	10.250	7.568	17.82	35.17	47.6	20.23	0.389	1051	40139	97.4
4A2	47.2	123.7	355.05	19.817	0	19.82	17.92	-	17.92	0.420	492	397	

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4.2   Destruction Efficiency

For this discussion, "destruction efficiency" is defined as the percentage of the inducted hydrocarbons that are destroyed during combustion.   For each condition, the concentration of hydrocarbons is measured in the intake and exhaust gases, and compared to a reference measurement with no inducted hydrocarbons:

$$\text{destruction efficiency} = \frac{\text{Intake HC} - (\text{Exhaust HC (measured)} - \text{Exhaust HC (reference)})}{\text{Intake HC}} \times 100\%$$

To examine the effect of engine load on hydrocarbon destruction efficiency given a certain concentration of gaseous fuel available, Figure 8 presents the destruction efficiency data acquired relative to the gaseous fuel flow rate for the four engine load ranges tested. Predictably, the proportion of hydrocarbons in the inlet air stream burned increases with increasing engine load. The useable range is limited by engine knock, which starts to occur in the light blue region indicated. The region is bounded at the lower-left by points where no knock occurred, and at the top by points where knock was detected. No destruction efficiency targets have been identified, but the figure outlines possible operational regions.
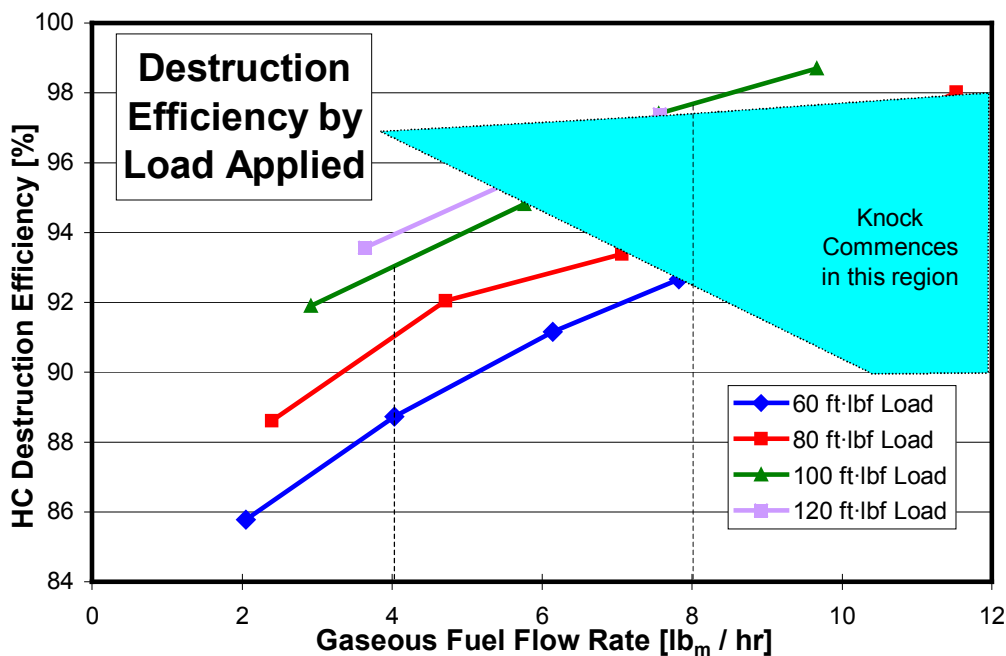
Figure 8. HC Destruction Efficiency by Load Applied

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4.3   Fuel Required

The cost of the higher engine load required to realize the higher destruction efficiency for a given intake concentration of gaseous fuel is increased use of added liquid fuel. Figure 9 quantifies the distillate fuel flow rates required for these same conditions. The dashed lines on Figures 8 and 9 indicate that, with 4 lb_m/hr of gaseous fuel entering the engine, increasing the destruction efficiency from 88.7% to 93.0%, a 4.9% improvement, demands a 70.5% increase in added liquid fuel, from 6.1 lb_m/hr to 10.4 lb_m/hr. Similarly, with 8 lb_m/hr of gaseous fuel entering the engine, increasing the destruction efficiency from 92.8% to 97.7%, a 5.2% improvement, demands a 337% increase in added liquid fuel, from 1.6 lb_m/hr to 6.9 lb_m/hr.
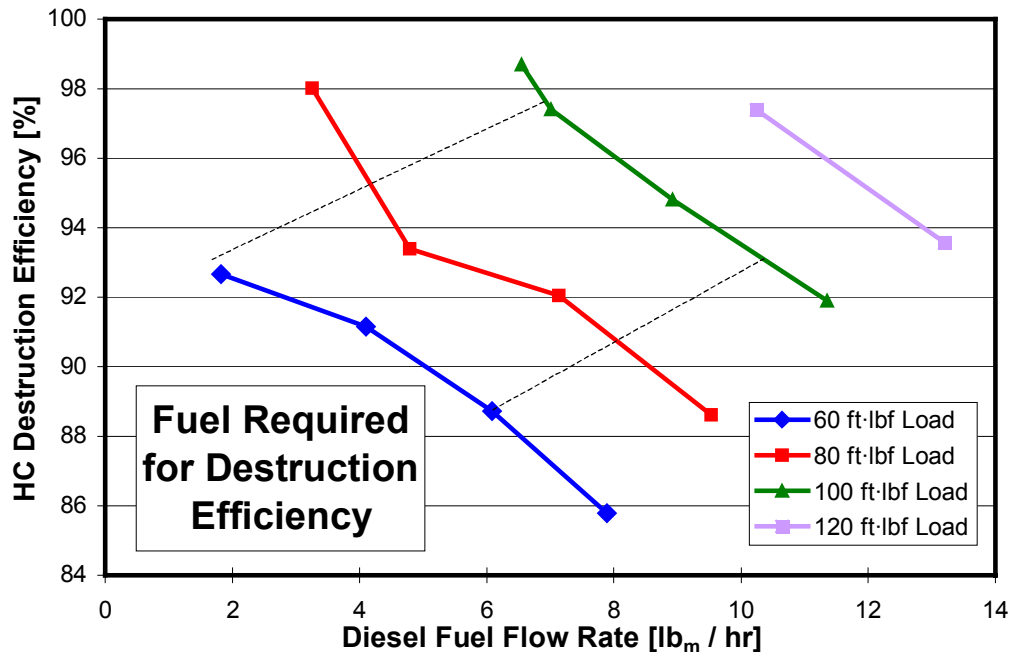
Figure 9.   Additional Liquid Fuel Required for Destruction Efficiency

4.4   Throttled Operation

In order to characterize the operation of the engine under the high intake vacuum conditions required to produce well suction, a series of test data was acquired with the engine intake throttled. A manually-operated butterfly valve was added to the intake

tract, downstream of the "gas ring" so that the throttled flow would be a mixture of intake air and gaseous fuel.

Figure 10 is a plot of some of these data, showing the effect on mass air flow of various intake manifold pressure conditions. The tightly-clustered blue lines indicate that the gas concentration of the intake air flow has little effect on the total mass flow at 1550 rpm. The effect is repeated for the testing at 2000 rpm. Another effect shown in the data is that the air flow is a strong function of engine speed. Predictably, for comparable engine vacuum conditions, the 1/3 increase in speed from 1550 rpm to 2000 rpm results in approximately 1/3 more mass air flow. Both sets of lines, if extrapolated to reach the point at which air flow reaches zero, would do so at approximately 50 kPaa. This indicates the engine would cease to operate, for lack of air, at a vacuum of less than 50 kPaa. In fact, the points at the lower-right ends of the curves shown are those at which the engine approached a condition where it would begin to misfire, lacking sufficient air for good combustion. Finally, the one line of data shown at a higher load verifies that engine load has no effect on intake air flow for a given set of intake conditions.
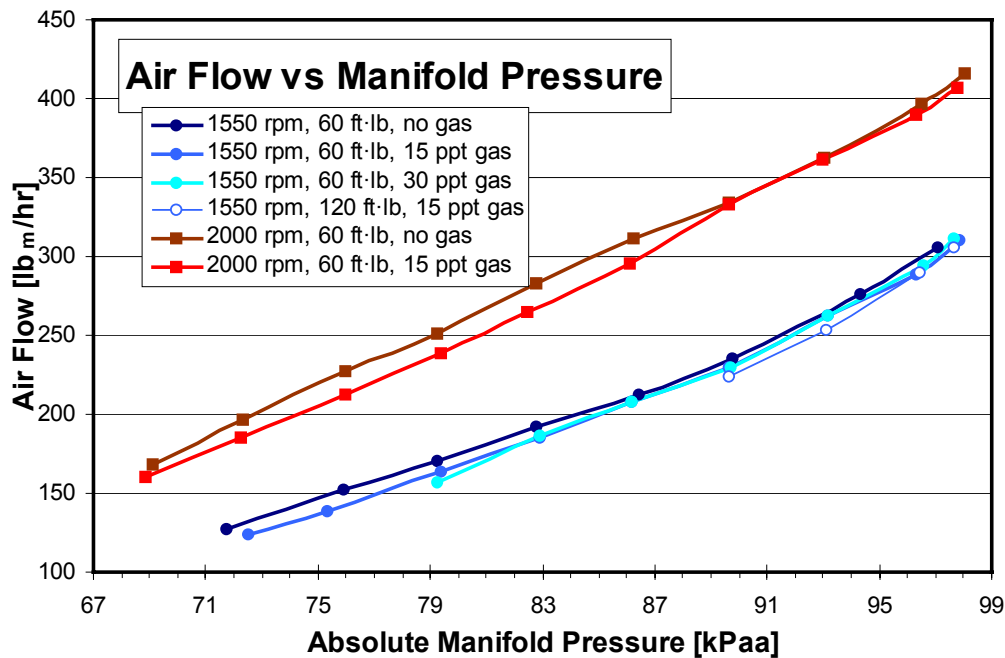
Figure 10. Air Flow vs. Intake Manifold Pressure, Engine Throttled

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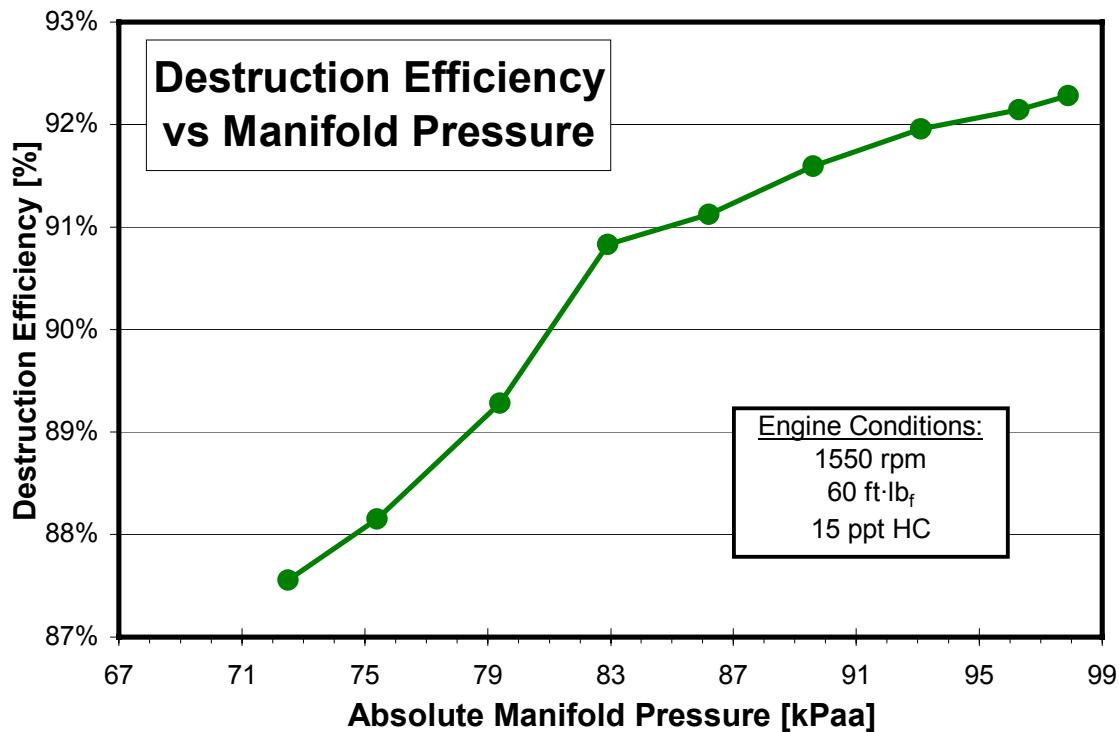
Figure 11. HC Destruction Efficiency vs. Intake Manifold Pressure

A number of engine characteristics that might have become problematic with reduced air flow were monitored, but none in fact reached unacceptable conditions. Temperatures of exhaust, cooling air and oil all stayed within acceptable limits, given that the engine inducted sufficient air for good combustion.   Even good hydrocarbon destruction efficiency was maintained, as shown in Figure 11, though it did start to fall off as manifold vacuum increased.

The result of the testing is simply that the engine will continue to operate, and will continue to destroy inducted hydrocarbons, so long as the engine has sufficient air — and the air contains sufficient oxygen — for good combustion. If enough oxygen can not be extracted from the well, outside air must be added to the intake stream, thereby reducing the flow from the well.

5.0   CONCLUSIONS

First and foremost, the diesel engine system is capable of performing the hydrocarbon vapor destruction task. Its success with a variety of hydrocarbon gases bodes well for the unknown conditions it will encounter at various well sites.

The system does have some characteristics that will limit its operation in actual use. The engine must have sufficient oxygen for good combustion. If the well gas hydrocarbon concentration is too high, its flow must be limited to the point that some liquid fuel is still needed by the engine. Finally, if high destruction efficiency is desired, additional fuel will be required.

The engine damage that occurred in the test cell resulted from conditions unlikely to be experienced at a field test site. Proper configuration of the engine system, and possibly some adsorption system or dryer, should avoid a recurrence of the problem.

6.0   RECOMMENDATIONS

Having proved the concept under laboratory conditions, the test rig should proceed to a field test, under appropriate conditions. The field test site should be one in reasonable proximity to Southwest Research, with a well or wells of known concentration and composition. The field test should last long enough to quantify vapor destruction and fuel use, and to experience any conditions that will have to be dealt with at field sites.

At sites where it is needed, an adsorption device should be prepared or purchased and added to the engine system. The adsorber should mitigate large peaks in hydrocarbon concentration from dense wells, and remove excess water from the intake stream.

The project should consider using a different engine for this purpose. Much of the hydrocarbons in the exhaust is created by incomplete combustion of the added liquid fuel. In short, the engine technology is old, making the engine's exhaust unnecessarily dirty.

An engine with electronically-controlled unit injectors with emit an order of magnitude less hydrocarbons and will be more fuel-efficient.

An exhaust catalyst, likely a diesel oxidation catalyst, could be added to the device, further reducing exhaust hydrocarbons by 90-98%.

A device other than an air compressor would offer the opportunity to harness the energy created by the engine system for useful work. If a diesel-driven electrical generator were employed, the electricity generated could be used, for instance, to pump the gases out of the ground; to blow air, perhaps heated air, into the ground to accelerate recovery; or to operate some sort of catalytic aftertreatment. Any remaining available electrical energy could be fed to a local power grid, or used for constructive purposes in the vicinity of the well.

APPENDIX A

RAW DATA

Run #	Date (d mmm yy)	Time (h:mm:ss)	Test Comment	Temp- RH °F	Relative Humidity %	JP-8 Fuel In °F	Pentane Fuel In °F	Inlet Air (LFE) °F	Intake Manifold Air °F	Oil Sump °F	Engine Cooling Air In °F	Engine Cooling Air Out °F	Exhaust Cylinder #1 °F	Exhaust Stack °F	Engine Power bhp	BSFC lb/bhp·hr	A/F Ratio LFE Total :1	Total Fuel Flow lb/hr	% Pilot JP-8 %	Air Flow LFE Dry lb/hr	Air Flow LFE Wet lb/hr	A/F Ratio LFE JP-8 only :1	Air Flow LFE acfm	Air / Gaseous Fuel Ratio :1	Engine Speed rpm	LFE ΔP " h2O	Intake Manif Press psia	Baro Press psia	JP-8 Fuel Flow lb/hr	Gaseous Fuel Flow lb/hr	Torque ft·lb	Exhaust HC ppm	Intake HC ppm	Dew Point °F	LFE Air Density lb/ft³
Propane, Test Condition 1																																			
1	19 Jan 02	12:03:05	TC1A1	77.1	21.8	88.1	71.3	74.0	76.6	178.0	70.1	136.7	535.5	509.0	23.1	0.469	37.68	10.81	91.6	402.64	404.39	40.66	93.25	444.59	2001.0	1.719	14.12	14.41	9.904	0.906	60.5	2	2	35.1	0.073
2	19 Jan 02	12:27:46	TC1B	77.6	21.3	91.6	71.6	74.2	77.1	186.1	70.1	138.5	538.5	511.3	22.9	0.458	38.72	10.48	79.3	401.05	402.79	48.23	93.00	184.90	2001.9	1.715	14.11	14.40	8.315	2.169	60.1	2	2	34.9	0.073
3	19 Jan 02	12:51:45	TC1C	78.1	22.2	92.4	72.2	76.0	78.0	186.3	70.8	139.4	557.1	528.4	23.3	0.456	38.01	10.61	62.9	399.38	401.21	59.78	92.78	101.56	2002.0	1.715	14.10	14.40	6.680	3.932	61.1	2	2	36.4	0.073
4	19 Jan 02	13:26:06	TC1D	78.0	20.3	93.8	73.6	78.8	79.7	186.1	71.3	139.4	583.3	554.8	22.9	0.534	32.85	12.19	40.5	398.79	400.46	80.70	92.59	55.00	2002.9	1.718	14.10	14.39	4.942	7.251	59.9	2	2	34.0	0.072
5	19 Jan 02	13:39:57	TC1E	78.0	20.3	94.3	73.9	77.2	79.5	186.7	72.1	139.7	647.7	602.5	22.6	0.652	26.94	14.74	21.1	394.09	395.74	126.74	91.53	33.90	2002.1	1.695	14.10	14.39	3.110	11.626	59.3	2	2	34.0	0.072
6	19 Jan 02	14:02:05	TC1A2	78.2	19.9	93.5	72.0	74.9	78.2	189.1	71.4	141.2	531.7	505.3	22.8	0.428	41.62	9.75	100.0	401.64	402.81	41.13	93.20	-	2002.3	1.721	14.10	14.39	9.753	-0.107	59.8	2	2	33.7	0.073
Propane, Test Condition 2																																			
1	19 Jan 02	15:43:22	TC2A1	78.5	20.3	83.8	68.8	70.7	74.0	174.7	67.1	138.4	657.5	617.0	30.6	0.400	33.19	12.26	100.0	398.81	400.51	32.52	92.73	-	2001.6	1.702	14.10	14.39	12.262	-0.626	80.3	2	2	34.4	0.073
2	19 Jan 02	16:23:32	TC2B	78.5	19.8	90.3	68.9	71.2	74.5	194.9	66.8	143.9	670.5	632.1	31.7	0.399	32.08	12.61	80.8	396.98	398.62	38.95	92.26	163.82	2006.3	1.694	14.10	14.39	10.192	2.423	82.9	2	2	33.8	0.073
3	19 Jan 02	16:49:42	TC2C	78.5	19.6	92.3	68.9	73.1	76.6	196.2	69.2	146.0	694.5	650.8	32.7	0.415	29.51	13.56	59.1	394.01	395.62	49.16	91.55	71.04	2000.9	1.686	14.11	14.39	8.015	5.547	85.8	2	2	33.6	0.073
4	19 Jan 02	17:08:46	TC2D	78.4	19.5	92.2	68.5	72.8	76.0	194.8	68.7	146.1	722.6	678.9	32.6	0.410	29.91	13.36	41.8	393.25	394.85	70.38	91.37	50.58	2002.1	1.682	14.11	14.39	5.587	7.775	85.6	2	2	33.4	0.073
5	19 Jan 02	17:19:09	TC2E	78.3	19.4	92.6	69.1	73.2	76.5	195.0	69.0	151.5	738.6	697.9	32.1	0.547	22.49	17.58	23.5	389.50	391.08	94.08	90.46	28.97	2004.0	1.666	14.11	14.39	4.140	13.443	84.2	2	2	33.2	0.073
6	19 Jan 02	17:27:41	TC2A2	78.1	19.2	92.5	68.8	72.8	76.6	196.0	68.5	147.4	694.7	653.8	32.3	0.447	27.88	14.45	100.0	396.65	398.22	27.46	92.07	-	2000.6	1.695	14.12	14.39	14.445	-0.130	84.9	2	2	32.7	0.073
Propane, Test Condition 3																																			
1	21 Jan 02	16:26:48	TC3A1	74.7	18.7	93.8	73.7	76.5	80.8	197.6	78.8	154.5	825.1	772.0	38.2	0.392	26.46	14.97	99.2	395.69	397.06	26.63	91.37	3385.25	2001.0	1.691	14.09	14.37	14.857	0.117	100.3	3	3	29.3	0.072
2	21 Jan 02	16:47:39	TC3B	74.9	19.0	98.1	74.2	77.1	81.3	207.8	79.2	157.4	802.0	749.1	38.2	0.389	26.45	14.86	80.0	392.88	394.27	33.03	90.79	132.25	2001.1	1.681	14.09	14.36	11.894	2.971	100.4	3	3	29.9	0.072
3	21 Jan 02	17:04:39	TC3C	74.9	19.5	99.0	74.6	77.0	81.2	208.8	78.2	156.0	794.2	741.7	38.3	0.384	26.60	14.72	60.6	391.05	392.47	43.85	90.38	67.42	2001.5	1.674	14.09	14.36	8.918	5.800	100.5	3	3	30.5	0.072
4	21 Jan 02	17:28:57	TC3D	75.6	20.3	99.2	75.1	77.0	81.0	207.0	78.4	155.4	802.2	751.4	38.2	0.391	26.15	14.93	40.5	389.26	390.77	64.44	90.12	43.81	2001.4	1.668	14.09	14.36	6.040	8.886	100.2	3	3	32.1	0.072
5	21 Jan 02	17:52:08	TC3E	76.4	20.5	100.0	75.0	77.0	81.2	205.8	78.8	155.3	883.6	828.4	38.4	0.430	23.50	16.50	19.9	386.16	387.71	117.76	89.54	29.20	2002.4	1.658	14.09	14.36	3.279	13.223	100.6	3	3	33.0	0.072
6	21 Jan 02	18:08:57	TC3A2	76.7	20.4	97.3	74.0	76.6	81.0	209.2	78.8	158.0	829.5	775.7	38.4	0.390	26.34	14.98	99.9	392.35	393.94	26.22	91.05	28100.62	2002.3	1.685	14.08	14.36	14.966	0.014	100.8	3	3	33.1	0.072
Propane, Test Condition 4																																			
1	21 Jan 02	21:18:03	TC4A1	76.9	21.5	96.6	73.6	76.6	81.5	223.8	77.5	169.8	1019.0	959.5	46.0	0.405	20.87	18.62	98.0	386.08	387.73	21.15	89.58	1052.85	2000.3	1.657	14.11	14.38	18.251	0.367	120.8		3	34.6	0.072
2	21 Jan 02	21:34:09	TC4B	76.8	21.6	97.8	73.0	76.0	80.6	221.6	75.5	166.9	956.7	898.4	45.9	0.386	21.87	17.71	80.9	384.63	386.22	26.85	89.21	113.57	2002.3	1.649	14.10	14.38	14.325	3.386	120.5		3	34.6	0.072
3	21 Jan 02	21:54:55	TC4C	76.9	21.7	98.7	72.8	75.3	79.9	219.8	76.2	166.0	918.7	860.1	45.9	0.367	22.89	16.86	60.3	382.63	384.29	37.63	88.78	57.18	2001.8	1.640	14.11	14.38	10.168	6.691	120.6		3	34.8	0.073
4	21 Jan 02	22:13:08	TC4D	76.9	21.8	98.5	72.8	75.1	79.4	217.7	75.2	164.0	903.2	844.8	46.0	0.363	23.06	16.72	40.7	381.90	383.56	56.10	88.60	38.54	2002.4	1.636	14.11	14.38	6.807	9.908	120.6		3	34.9	0.073
5	21 Jan 02	22:48:39	TC4E	76.9	23.1	98.3	72.6	75.3	79.4	209.4	76.2	160.1	945.3	886.5	45.8	0.360	23.34	16.49	20.8	381.30	383.26	111.26	88.53	29.21	2000.7	1.635	14.11	14.38	3.429	13.060	120.2		3	36.4	0.073
6	21 Jan 02	23:19:45	TC4A2	76.9	24.2	95.7	72.5	75.8	80.6	216.8	76.4	166.8	1023.4	961.0	45.9	0.398	21.30	18.28	99.5	386.22	388.08	21.23	89.69	4315.94	2001.8	1.658	14.11	14.38	18.192	0.089	120.5		3	37.6	0.072
Propane, Max Torque at 2000 & hot																																			
37	21 Jan 02	23:41:36	maxTQ	76.9	24.2	95.8	72.9	76.7	81.8	223.9	77.8	180.4	1220.2	1157.9	51.4	0.428	17.46	21.99	99.3	381.53	383.37	17.48	88.62	2376.79	2004.2	1.640	14.11	14.37	21.833	0.161	134.8	4	4	37.6	0.072
Butane, Test Condition 1																																			
44	23 Jan 02	18:23:57	TC1A1	80.2	50.9	97.2	79.0	80.6	84.1	183.8	82.1	143.3	551.1	522.2	22.9	0.436	39.27	9.98	97.4	388.68	393.16	39.97	92.68	1507.10	2000.8	1.722	13.96	14.24	9.725	0.258	60.1	2	2	60.3	0.071
45	23 Jan 02	18:45:10	TC1B	80.1	51.0	100.1	79.0	80.6	84.1	192.2	80.8	145.0	551.7	523.2	23.0	0.451	37.80	10.35	80.4	388.09	392.56	46.62	92.51	191.40	2002.5	1.719	13.96	14.24	8.325	2.028	60.2	2	2	60.3	0.071
46	23 Jan 02	18:58:34	TC1C	80.0	50.9	100.2	78.7	80.2	83.7	192.1	80.9	143.4	560.6	530.7	23.0	0.469	36.29	10.76	60.9	387.24	391.68	59.73	92.27	90.46	2002.2	1.714	13.96	14.24	6.484	4.281	60.2	2	2	60.2	0.071
47	23 Jan 02	19:12:45	TC1D	79.9	51.2	100.0	78.7	79.9	83.3	191.2	80.0	141.8	573.8	544.8	23.0	0.510	33.30	11.73	40.2	387.14	391.59	82.09	92.23	55.18	2004.3	1.712	13.96	14.24	4.716	7.016	60.3	2	2	60.2	0.071
48	23 Jan 02	19:25:16	TC1E	79.9	52.3	100.3	78.5	79.5	82.8	191.2	79.8	143.0	611.5	574.3	22.9	0.624	27.21	14.27	19.9	384.59	389.10	135.31	91.62	33.65	2002.0	1.700	13.97	14.25	2.842	11.431	60.1	2	2	60.8	0.071
49	23 Jan 02	19:46:05	TC1A2	79.9	54.2	99.7	77.6	79.5	83.0	193.2	79.9	144.6	549.5	519.9	23.0	0.436	39.16	10.02	97.8	388.50	393.22	39.67	92.61	1727.33	2001.3	1.718	13.97	14.25	9.794	0.225	60.3	2	2	61.8	0.071
Butane, Test Condition 2																																			
53	23 Jan 02	20:37:13	TC2A1	79.2	51.6	96.7	76.4	78.5	82.2	191.9	77.9	148.8	676.0	637.8	30.6	0.405	31.46	12.41	98.0	386.37	390.74	31.76	91.86	1582.84	2001.0	1.702	13.97	14.25	12.165	0.244	80.4	2	2	59.8	0.071
54	23 Jan 02	20:51:39	TC2B	79.3	53.1	98.8	76.3	78.5	82.2	198.5	78.5	149.3	669.5	629.5	30.6	0.405	31.46	12.38	80.6	385.30	389.81	38.63	91.70	160.42	2001.4	1.699	13.97	14.25	9.975	2.402	80.2	2	2	60.8	0.071
55	23 Jan 02	21:03:23	TC2C	79.6	53.8	99.3	76.5	78.6	82.1	199.3	79.1	148.5	663.5	624.6	30.6	0.409	31.07	12.52	60.9	384.90	389.50	50.46	91.66	78.63	2001.4	1.699	13.97	14.25	7.628	4.895	80.3	2	2	61.4	0.071
56	23 Jan 02	21:14:06	TC2D	79.5	53.5	99.4	76.7	78.5	82.0	198.1	78.7	146.5	672.8	633.4	30.8	0.424	29.80	13.04	40.5	384.34	388.91	72.77	91.51	49.54	2002.5	1.686	13.97	14.25	5.282	7.758	80.8	2	2	61.2	0.071
57	23 Jan 02	21:22:43	TC2E	79.5	53.7	99.7	77.1	78.6	82.1	198.1	78.2	150.4	705.6	652.8	29.8	0.519	24.75	15.45	21.2	378.16	382.65	115.45	90.02	31.07	2000.6	1.668	13.97	14.25	3.276	12.171	78.2	2	2	61.2	0.071
58	23 Jan 02	21:30:19	TC2A2	79.4	53.7	99.9	76.6	78.5	82.5	200.7	77.8	151.3	682.9	640.8	30.8	0.407	31.08	12.54	98.5	385.46	390.03	31.23	91.73	1998.65	2002.6	1.700	13.98	14.25	12.344	0.193	80.8	2	2	61.1	0.071
Butane, Test Condition 3																																			
62	25 Jan 02	17:29:50	TC3A1	78.0	15.2	99.5	74.1	74.9	80.5	205.9	76.6	157.8	825.3	778.5	38.2	0.394	26.59	15.06	98.6	396.39	397.63	26.70	91.48	1882.66	2002.1	1.689	14.18	14.46	14.848	0.211	100.2	-1	0	26.9	0.073
63	25 Jan 02	17:40:36	TC3B	77.8	14.5	101.2	74.9	74.9	80.6	208.9	76.1	158.7	795.5	752.6	38.3	0.388	26.88	14.87	80.6	395.88	397.05	33.03	91.29	137.29	2003.3	1.686	14.18	14.46	11.986	2.884	100.5	-1	0	25.6	0.073
64	25 Jan 02	17:58:39	TC3C	77.9	14.6	102.1	78.8	74.6	80.3	209.7	74.9	157.1	768.2	727.1	38.1	0.384	27.29	14.64	61.5	395.26	396.43	43.94	91.16	70.08	2002.7	1.682	14.18	14.46	8.996	5.640	99.9	-1	0	25.9	0.073
65	25 Jan 02	18:09:27	TC3D	78.0	14.6	102.0	80.6	74.5	80.3	208.6	74.8	156.8	753.9	714.4	38.2	0.379	27.56	14.47	41.1	394.41	395.58	66.31	90.98	46.30	2001.9	1.679	14.18	14.46	5.948	8.519	100.2	-1	0	25.9	0.073
66	25 Jan 02	18:21:31	TC3E	78.0	14.7	101.9	81.5	74.9	80.8	207.4	74.4	152.6	771.0	735.0	38.2	0.392	26.50	14.97	20.0	392.67	393.85	131.36	90.57	32.77	2001.4	1.672	14.18	14.46	2.989	11.983	100.3	-1	0	26.1	0.073
67	25 Jan 02	18:27:00	TC3A2	77.9	14.7	102.1	76.6	73.7	79.4	207.9	74.4	156.5	818.2	767.2	38.1	0.386	27.23	14.73	99.8	396.27	397.46	26.96	91.38	14102.01	2001.6	1.684	14.18	14.46	14.701	0.028	100.1	-1	0	26.0	0.073
Butane, Test Condition 4																																			
71	25 Jan 02	19:02:05	TC4A1	77.4	15.8	89.3	67.2	70.5	75.2	200.4	72.6	157.3	1001.7	939.7	46.0	0.403	21.57	18.55	98.3	393.18	394.43	21.56	90.56	1267.16	2001.8	1.662	14.19	14.47	18.238	0.310	120.7	-1	0	27.4	0.074
72	25 Jan 02	19:20:33	TC4B	77.3	15.8	92.2	67.6	70.3	75.1	210.7	71.5	158.2	944.6	885.1	45.7	0.387	22.60	17.67	81.3	392.67	393.80	27.33	90.38	118.67	2001.6	1.658	14.19	14.47	14.366	3.308	119.9	-1	0	27.2	0.074
73	25 Jan 02	19:31:55	TC4C	77.2	15.8	92.9	67.8	70.1	74.8	211.6	71.4	158.6	896.6	837.3	46.0	0.375	23.05	17.23	60.4	390.08	391.31	37.51	89.80	57.13	2000.4	1.646	14.20	14.47	10.399	6.828	120.8	-1	0	27.2	0.074
74	25 Jan 02	19:45:59	TC4D	77.2	15.8	93.2	68.0	69.7	74.4	213.3	70.3	159.6	858.8	804.2	45.6	0.371	23.34	16.90	43.4	387.27	388.48	52.84	89.15	40.46	1997.9	1.634	14.19	14.47	7.329	9.573	119.8	-1	0	27.2	0.074
75	25 Jan 02	19:51:10	TC4A2	77.2	15.6	93.3	67.4	69.7	74.5	213.1	71.2	159.8	1001.3	922.9	45.9	0.407	21.41	18.68	98.5	392.63	393.85	21.34	90.38	1395.78	2001.7	1.656	14.20	14.47	18.397	0.281	120.4	-1	0	26.9	0.074
Pentane, Exploratory Tests																																			
79	6 Feb 02	21:34:53	TC1A	0.0	29.37	91.2	67.3	68.2	73.3	194.7	71.4	148.0	806.1	759.9	38.1	0.388	27.43	14.77	100.0	464.90	465.03	31.49	91.42	-	2001.0	1.671	14.17	14.44	14.766	-0.250	100.0	314	41	-24.4	0.074

Butane, Test Condition 1, HC Sampling

Run #	Date (d mmm yy)	Time (h:mm:ss)	Test Comment	Temp-RH °F	Relative Humidity %	JP-8 Fuel In °F	Pentane Fuel In °F	Inlet Air (LFE) °F	Intake Manifold Air °F	Oil Sump °F	Engine Cooling Air In °F	Engine Cooling Air Out °F	Exhaust Cylinder #1 °F	Exhaust Stack °F	Engine Power bhp	BSFC lb/bhp·hr	A/F Ratio LFE Total :1	Total Fuel Flow lb/hr	% Pilot JP-8 %	Air Flow LFE Dry lb/hr	Air Flow LFE Wet lb/hr	A/F Ratio LFE JP-8 only :1	Air Flow LFE acfm	Air / Gaseous Fuel Ratio :1	Engine Speed rpm	LFE ΔP " h2O	Intake Manif Press psia	Baro Press psia	JP-8 Fuel Flow lb/hr	Gaseous Fuel Flow lb/hr	Torque ft·lb	Exhaust HC ppm	Intake HC ppm	Dew Point °F	LFE Air Density lb/ft³
83	12 Feb 02	10:54:21	TC1A - HC	71.2	19.1	81.7	61.7	64.4	67.5	171.5	64.6	128.0	521.6	494.8	22.9	0.437	41.94	9.99	98.2	411.64	412.93	41.96	93.82	2353.76	2000.7	1.706	14.16	14.45	9.811	0.175	60.1	650	24	27.0	0.074
84	12 Feb 02	13:56:57	TC1A1 - HC	74.4	16.5	86.9	67.5	69.4	72.9	173.7	69.9	132.6	531.8	505.5	22.8	0.428	41.99	9.78	100.0	405.13	406.35	41.42	93.21	-	2001.0	1.708	14.11	14.40	9.782	-0.017	59.9	639	41	26.0	0.073
85	12 Feb 02	14:08:16	TC1B - HC	74.8	16.2	90.4	67.8	69.9	73.3	181.0	70.2	134.7	531.8	504.8	22.8	0.445	40.36	10.13	82.6	403.51	404.72	48.22	92.92	228.43	2001.1	1.703	14.12	14.40	8.368	1.766	59.8	1882	11187	25.9	0.073
86	12 Feb 02	14:11:25	TC1B - HC	74.8	16.2	90.9	67.8	69.8	73.4	182.0	70.5	135.1	531.7	504.2	22.8	0.453	39.67	10.33	81.1	404.32	405.54	48.28	93.10	206.54	2001.0	1.707	14.12	14.40	8.374	1.958	59.9	1874	11022	25.9	0.073
87	12 Feb 02	14:22:09	TC1C - HC	75.1	16.4	92.1	68.4	70.4	73.7	183.4	70.2	134.3	542.9	514.2	22.9	0.493	36.18	11.27	58.1	402.44	403.67	61.48	92.74	85.16	2002.3	1.701	14.12	14.40	6.546	4.726	60.0	2669	26223	26.4	0.073
88	12 Feb 02	14:27:42	TC1C - HC	75.1	16.4	92.4	68.5	70.1	73.7	183.9	69.8	135.0	539.5	511.8	22.9	0.481	37.18	10.99	62.9	403.04	404.28	58.35	92.89	98.73	2002.3	1.703	14.11	14.40	6.908	4.082	60.0	2681	22648	26.4	0.073
89	12 Feb 02	14:31:23	TC1C - HC	75.1	16.4	92.5	68.3	69.9	73.5	183.9	70.9	135.1	540.0	512.4	22.9	0.493	36.12	11.31	60.1	402.62	403.85	59.29	92.80	89.15	2003.7	1.701	14.12	14.40	6.790	4.516	60.1	2670	25680	26.4	0.073
90	12 Feb 02	14:39:45	TC1D - HC	75.4	15.7	92.7	68.6	70.3	73.7	183.6	69.8	133.2	553.5	526.0	22.8	0.516	34.68	11.76	40.6	402.33	403.52	84.21	92.78	57.59	2002.0	1.702	14.11	14.39	4.778	6.986	59.8	2662	35392	25.6	0.073

Butane, Test Condition 2, HC Sampling

Run #	Date	Time	Test Comment	Temp-RH	RH%	JP-8 Fuel In	Pentane Fuel In	Inlet Air (LFE)	Intake Manifold Air	Oil Sump	Eng Cool Air In	Eng Cool Air Out	Exh Cyl #1	Exh Stack	Eng Power	BSFC	A/F LFE Total	Total Fuel Flow	% Pilot JP-8	Air Flow LFE Dry	Air Flow LFE Wet	A/F LFE JP-8 only	Air Flow LFE acfm	Air/Gas Fuel Ratio	Eng Speed	LFE ΔP	Intake Manif Press	Baro Press	JP-8 Fuel Flow	Gaseous Fuel Flow	Torque	Exh HC	Intake HC	Dew Point	LFE Air Density
94	12 Feb 02	15:17:41	TC2A1 - HC	76.1	15.9	95.6	69.8	71.8	76.0	197.3	71.0	146.4	659.5	622.5	30.6	0.401	32.82	12.26	100.0	397.60	398.83	32.42	91.84	-	2000.8	1.688	14.11	14.39	12.265	-0.676	80.3	605	42	26.5	0.073
95	12 Feb 02	15:44:23	TC2B - HC	76.8	16.1	96.2	70.0	71.8	75.9	196.6	73.9	146.0	656.3	617.7	30.9	0.406	32.17	12.52	80.1	397.31	398.58	39.60	91.92	159.52	2003.3	1.690	14.11	14.39	10.033	2.491	81.0	1577	15900	27.4	0.073
96	12 Feb 02	15:57:23	TC2C - HC	77.4	15.0	96.4	70.2	72.3	76.0	195.9	71.6	144.9	651.5	613.9	30.8	0.412	31.59	12.71	59.8	396.03	397.23	52.08	91.72	77.52	2002.9	1.687	14.11	14.39	7.604	5.109	80.9	2660	33804	26.1	0.073

Butane, Test Condition 3, HC Sampling

Run #	Date	Time	Test Comment	Temp-RH	RH%	JP-8 Fuel In	Pentane Fuel In	Inlet Air (LFE)	Intake Manifold Air	Oil Sump	Eng Cool Air In	Eng Cool Air Out	Exh Cyl #1	Exh Stack	Eng Power	BSFC	A/F LFE Total	Total Fuel Flow	% Pilot JP-8	Air Flow LFE Dry	Air Flow LFE Wet	A/F LFE JP-8 only	Air Flow LFE acfm	Air/Gas Fuel Ratio	Eng Speed	LFE ΔP	Intake Manif Press	Baro Press	JP-8 Fuel Flow	Gaseous Fuel Flow	Torque	Exh HC	Intake HC	Dew Point	LFE Air Density
100	12 Feb 02	16:13:45	TC3C - HC	77.7	14.6	97.4	71.1	72.7	77.1	203.5	73.4	153.5	760.2	713.5	38.2	0.389	26.75	14.83	59.7	391.30	392.46	44.20	90.68	65.47	2002.2	1.669	14.11	14.38	8.853	5.977	100.1	1959	35414	25.7	0.073
101	12 Feb 02	16:24:11	TC3D - HC	78.0	15.3	98.0	71.1	72.8	77.0	204.2	73.6	153.2	752.3	706.9	38.3	0.383	26.97	14.69	42.3	390.48	391.71	62.90	90.55	46.06	2002.5	1.667	14.11	14.39	6.208	8.477	100.5	2606	35135	27.1	0.073

Butane, Test Condition 4, HC Sampling

Run #	Date	Time	Test Comment	Temp-RH	RH%	JP-8 Fuel In	Pentane Fuel In	Inlet Air (LFE)	Intake Manifold Air	Oil Sump	Eng Cool Air In	Eng Cool Air Out	Exh Cyl #1	Exh Stack	Eng Power	BSFC	A/F LFE Total	Total Fuel Flow	% Pilot JP-8	Air Flow LFE Dry	Air Flow LFE Wet	A/F LFE JP-8 only	Air Flow LFE acfm	Air/Gas Fuel Ratio	Eng Speed	LFE ΔP	Intake Manif Press	Baro Press	JP-8 Fuel Flow	Gaseous Fuel Flow	Torque	Exh HC	Intake HC	Dew Point	LFE Air Density
105	12 Feb 02	16:36:54	TC4C - HC	78.0	14.2	99.5	72.0	73.5	78.5	213.6	75.3	167.8	914.0	855.6	46.8	0.381	21.81	17.82	56.1	383.72	384.85	38.36	88.96	49.08	2003.4	1.639	14.12	14.39	10.003	7.818	122.7	1386	35200	25.3	0.073
106	12 Feb 02	16:50:28	TC4E - HC	78.0	14.5	101.9	71.2	73.5	78.6	223.0	74.5	176.0	866.2	810.3	46.0	0.436	18.43	20.07	29.8	365.17	366.26	60.98	84.67	25.94	2005.3	1.560	14.13	14.39	5.988	14.079	120.5	604	35118	25.8	0.073

Pentane, Test Condition 1, HC Sampling

Run #	Date	Time	Test Comment	Temp-RH	RH%	JP-8 Fuel In	Pentane Fuel In	Inlet Air (LFE)	Intake Manifold Air	Oil Sump	Eng Cool Air In	Eng Cool Air Out	Exh Cyl #1	Exh Stack	Eng Power	BSFC	A/F LFE Total	Total Fuel Flow	% Pilot JP-8	Air Flow LFE Dry	Air Flow LFE Wet	A/F LFE JP-8 only	Air Flow LFE acfm	Air/Gas Fuel Ratio	Eng Speed	LFE ΔP	Intake Manif Press	Baro Press	JP-8 Fuel Flow	Gaseous Fuel Flow	Torque	Exh HC	Intake HC	Dew Point	LFE Air Density
110	1 Mar 02	10:02:24	TC1A1	79.8	35.0	95.9	67.3	69.5	75.4	190.5	71.3	140.6	562.8	533.8	23.2	0.431	39.10	10.02	100.0	391.69	393.40	39.10	92.15	-	2001.7	1.688	13.98	14.26	10.017	-0.508	61.0	638	4	34.8	0.029
111	1 Mar 02	10:22:33	TC1B	80.0	34.7	96.3	92.1	69.1	75.0	191.7	71.4	140.5	557.0	527.4	23.2	0.428	39.03	9.94	79.4	388.01	391.02	49.16	91.80	189.47	2003.1	1.681	13.98	14.26	7.893	2.048	60.9	1591	11194	49.7	0.029
112	1 Mar 02	10:33:05	TC1C	79.8	36	96.4	92.9	69.7	75.5	191.6	72.5	141.4	549.4	520.9	23.1	0.437	38.31	10.12	60.1	387.58	390.68	63.71	91.69	96.10	1999.7	1.680	13.98	14.26	6.083	4.033	60.8	2296	20365	50.4	0.029
113	1 Mar 02	10:41:29	TC1B2	79.8	36	96.4	92.3	70.3	76.1	191.6	73.0	141.2	560.4	530.2	23.3	0.427	39.05	9.96	80.5	389.00	392.11	48.48	92.04	200.76	2005.0	1.688	13.98	14.26	8.024	1.938	61.1	1702	10723	50.4	0.028
114	1 Mar 02	10:52:27	TC1D	79.8	36	96.9	95.1	69.7	76.1	192.2	72.8	143.7	532.3	507.1	23.3	0.440	37.74	10.24	40.0	386.38	389.47	94.25	91.45	62.94	2001.4	1.676	13.97	14.25	4.099	6.139	61.1	2660	30072	50.4	0.028
115	1 Mar 02	11:03:34	TC1E	80.0	36.8	98.4	100.3	70.4	77.3	195.0	72.8	146.6	511.8	487.9	23.1	0.418	39.80	9.65	18.9	383.89	387.05	210.30	90.94	49.08	2002.6	1.668	13.97	14.25	1.825	7.821	60.5	2751	37461	51.2	0.028
116	1 Mar 02	11:10:54	TC1A2	80.1	36.7	98.5	79.5	71.0	77.1	195.2	71.8	143.4	565.0	533.4	23.2	0.431	38.85	9.98	100.0	387.79	390.98	38.85	91.87	-	2001.7	1.686	13.97	14.25	9.982	-0.411	60.8	697	5	51.2	0.028

Pentane, Test Condition 2, HC Sampling

Run #	Date	Time	Test Comment	Temp-RH	RH%	JP-8 Fuel In	Pentane Fuel In	Inlet Air (LFE)	Intake Manifold Air	Oil Sump	Eng Cool Air In	Eng Cool Air Out	Exh Cyl #1	Exh Stack	Eng Power	BSFC	A/F LFE Total	Total Fuel Flow	% Pilot JP-8	Air Flow LFE Dry	Air Flow LFE Wet	A/F LFE JP-8 only	Air Flow LFE acfm	Air/Gas Fuel Ratio	Eng Speed	LFE ΔP	Intake Manif Press	Baro Press	JP-8 Fuel Flow	Gaseous Fuel Flow	Torque	Exh HC	Intake HC	Dew Point	LFE Air Density
120	1 Mar 02	13:38:03	TC2A1	78.8	41.8	99.6	70.9	74.2	80.3	201.2	76.7	152.5	691.3	651.4	30.6	0.398	31.61	12.18	100.0	385.01	388.44	31.61	91.33	-	2001.6	1.683	13.94	14.22	12.181	-0.428	80.3	668	2	53.3	0.028
121	1 Mar 02	13:52:53	TC2B	79.4	41.1	101.7	92.7	75.0	80.9	204.9	77.8	153.7	683.5	644.0	30.5	0.391	32.13	11.93	79.9	383.12	386.59	40.20	91.03	160.00	2002.5	1.680	13.93	14.21	9.531	2.394	80.0	1471	12918	53.7	0.029
122	1 Mar 02	14:01:42	TC2C	79.4	41	102.2	93.3	74.9	81.4	205.9	77.9	154.6	666.5	628.6	30.2	0.392	32.14	11.85	60.2	380.98	384.42	53.39	90.54	80.76	1998.4	1.670	13.93	14.21	7.136	4.717	79.5	1913	24038	53.6	0.029
123	1 Mar 02	14:11:28	TC2D	79.5	41.4	103.0	98.7	75.2	82.3	207.8	77.5	157.5	642.0	607.7	30.6	0.388	32.02	11.85	40.4	379.51	382.99	79.21	90.25	53.74	2004.5	1.666	13.93	14.20	4.791	7.062	80.1	2335	35343	54.0	0.029
124	1 Mar 02	14:20:04	TC2E	79.5	40.9	105.1	108.3	75.4	85.7	225.5	78.0	202.3	804.5	729.9	29.6	0.499	23.37	14.78	22.0	345.46	348.58	106.01	82.15	29.99	2000.1	1.516	13.96	14.20	3.259	11.520	77.7	1117	56357	53.6	0.030
125	1 Mar 02	14:38:43	TC2A2	79.3	41.1	105.9	74.2	76.6	83.1	217.9	78.2	160.1	707.2	665.1	30.7	0.402	30.75	12.32	100.0	378.67	382.09	30.75	90.05	-	2003.0	1.665	13.93	14.20	12.316	-0.360	80.4	678	3	53.6	0.029

Pentane, Test Condition 3, HC Sampling

Run #	Date	Time	Test Comment	Temp-RH	RH%	JP-8 Fuel In	Pentane Fuel In	Inlet Air (LFE)	Intake Manifold Air	Oil Sump	Eng Cool Air In	Eng Cool Air Out	Exh Cyl #1	Exh Stack	Eng Power	BSFC	A/F LFE Total	Total Fuel Flow	% Pilot JP-8	Air Flow LFE Dry	Air Flow LFE Wet	A/F LFE JP-8 only	Air Flow LFE acfm	Air/Gas Fuel Ratio	Eng Speed	LFE ΔP	Intake Manif Press	Baro Press	JP-8 Fuel Flow	Gaseous Fuel Flow	Torque	Exh HC	Intake HC	Dew Point	LFE Air Density
129	1 Mar 02	15:39:15	TC3A1	80.1	39.8	103.2	75.4	79.8	86.2	215.7	79.1	167.6	871.7	818.6	38.5	0.391	25.08	15.02	100.0	376.86	380.25	25.08	89.81	-	2002.4	1.668	13.92	14.19	15.024	-0.523	100.9	667	2	53.4	0.029
130	1 Mar 02	15:50:30	TC3B	80.1	39.4	105.9	93.0	80.3	86.7	220.5	79.1	169.3	839.9	790.8	38.1	0.375	26.29	14.27	79.5	375.17	378.50	33.06	89.40	128.48	2002.0	1.662	13.92	14.19	11.350	2.920	99.8	1402	17297	53.2	0.029
131	1 Mar 02	16:01:24	TC3C	80.3	39	107.6	96.6	80.4	87.6	223.5	80.9	171.8	823.4	774.2	39.0	0.376	25.38	14.68	60.7	372.56	375.87	41.77	88.82	64.65	2002.4	1.651	13.92	14.18	8.919	5.763	102.3	1566	30193	53.1	0.029
132	1 Mar 02	16:08:28	TC3D	80.3	38.7	109.6	106.2	81.2	90.2	234.9	80.7	200.9	914.6	842.1	37.9	0.428	21.64	16.22	40.4	350.89	353.97	53.59	83.64	36.30	2003.5	1.557	13.94	14.18	6.548	9.668	99.3	668	51027	52.8	0.030
133	1 Mar 02	16:14:52	TC3C+	80.5	38.4	111.9	105.1	81.5	91.1	248.7	81.2	191.9	849.2	807.6	38.5	0.379	24.92	14.57	48.1	363.03	366.22	51.78	86.57	48.05	2002.7	1.612	13.92	14.18	7.011	7.556	100.9	1036	39954	52.8	0.030
134	1 Mar 02	16:22:28	TC3A2	80.5	39.1	112.7	87.5	80.9	89.1	242.7	81.3	178.6	894.4	835.0	39.0	0.392	24.28	15.30	100.0	371.59	374.91	24.28	88.64	-	2002.0	1.649	13.92	14.18	15.301	-0.504	102.4	785	1	53.3	0.030

Pentane, Test Condition 4, HC Sampling

Run #	Date	Time	Test Comment	Temp-RH	RH%	JP-8 Fuel In	Pentane Fuel In	Inlet Air (LFE)	Intake Manifold Air	Oil Sump	Eng Cool Air In	Eng Cool Air Out	Exh Cyl #1	Exh Stack	Eng Power	BSFC	A/F LFE Total	Total Fuel Flow	% Pilot JP-8	Air Flow LFE Dry	Air Flow LFE Wet	A/F LFE JP-8 only	Air Flow LFE acfm	Air/Gas Fuel Ratio	Eng Speed	LFE ΔP	Intake Manif Press	Baro Press	JP-8 Fuel Flow	Gaseous Fuel Flow	Torque	Exh HC	Intake HC	Dew Point	LFE Air Density
138	1 Mar 02	17:22:08	TC4A1	81.5	36.1	112.9	80.6	83.3	90.7	235.7	78.2	181.9	1054.5	993.2	45.6	0.393	20.67	17.95	100.0	371.07	374.23	20.67	88.61	-	2002.9	1.654	13.93	14.19	17.948	-0.374	119.6	501	1	52.0	0.030
139	1 Mar 02	17:32:32	TC4B	81.8	35.6	114.4	93.5	83.5	90.9	237.1	78.4	182.1	992.4	933.4	45.8	0.368	21.99	16.84	78.4	370.28	373.42	28.05	88.45	101.80	2002.9	1.651	13.92	14.19	13.203	3.637	120.0	1330	20670	51.9	0.030
140	1 Mar 02	17:41:34	TC4C	81.8	35.6	115.8	103.4	83.6	92.1	242.8	78.6	194.4	1005.6	952.4	45.9	0.389	20.23	17.82	57.5	360.46	363.52	35.17	86.11	47.63	2000.5	1.608	13.93	14.18	10.250	7.568	120.4	1051	40139	51.9	0.031
141	1 Mar 02	18:01:30	TC4A2	82.5	34.2	116.0	88.7	79.6	90.9	268.7	77.5	205.8	1222.7	1171.3	47.2	0.420	17.92	19.82	100.0	355.05	358.01	17.92	84.91	-	2002.0	1.577	13.94	14.18	19.817	-0.140	123.7	492	397	51.4	0.031

No Gas, Engine Check Runs

Run #	Date	Time	Test Comment	Temp-RH	RH%	JP-8 Fuel In	Pentane Fuel In	Inlet Air (LFE)	Intake Manifold Air	Oil Sump	Eng Cool Air In	Eng Cool Air Out	Exh Cyl #1	Exh Stack	Eng Power	BSFC	A/F LFE Total	Total Fuel Flow	% Pilot JP-8	Air Flow LFE Dry	Air Flow LFE Wet	A/F LFE JP-8 only	Air Flow LFE acfm	Air/Gas Fuel Ratio	Eng Speed	LFE ΔP	Intake Manif Press	Baro Press	JP-8 Fuel Flow	Gaseous Fuel Flow	Torque	Exh HC	Intake HC	Dew Point	LFE Air Density
142	1 Nov 02	15:16:25	20-06-00-97.2	70.6	61.6	91.3	81.8	81.0	84.4	169.2	78.3	143.2	544.3	526.0	22.7	0.500	36.74	11.34	86.3	416.70	419.28	42.57	97.91	-	1996.2	1.819	14.10	14.34	9.790	1.552	59.7	683	33	56.8	0.071
143	1 Nov 02	15:22:15	20-08-00-97.3	71.6	60.3	97.2	87.1	85.1	88.8	183.7	83.0	159.0	680.2	650.8	30.2	0.447	30.44	13.51	89.5	411.18	413.69	34.01	97.32	-	1998.5	1.818	14.11	14.35	12.090	1.417	79.4	696	29	57.1	0.071
144	1 Nov 02	15:36:21	20-10-00-97.4	70.3	62.5	109.3	98.7	91.8	99.1	213.8	90.1	181.0	874.0	825.3	38.1	0.429	24.50	16.37	91.7	400.93	403.38	26.71	96.06	-	2001.3	1.808	14.12	14.35	15.009	1.358	100.1	705	25	57.1	0.070
145	1 Nov 02	15:49:31	20-12-00-97.4	69.5	64.1	117.3	108.7	98.7	108.1	235.8	92.6	207.0	1131.2	1080.8	45.7	0.442	19.37	20.21	93.8	391.30	393.76	20.64	94.96	-	1998.2	1.802	14.12	14.35	18.959	1.247	120.1	566	25	56.9	0.069

Engine Check Runs with Pentane

Run #	Date (d mmm yy)	Time (h:mm:ss)	Test Comment	Temp-RH °F	Relative Humidity %	JP-8 Fuel In °F	Pentane Fuel In °F	Inlet Air (LFE) °F	Intake Manifold Air °F	Oil Sump °F	Engine Cooling Air In °F	Engine Cooling Air Out °F	Exhaust Cylinder #1 °F	Exhaust Stack °F	Engine Power bhp	BSFC lb/bhp·hr	A/F Ratio LFE Total :1	Total Fuel Flow lb/hr	% Pilot JP-8 %	Air Flow LFE Dry lb/hr	Air Flow LFE Wet lb/hr	A/F Ratio LFE JP-8 only :1	Air Flow LFE acfm	Air/Gaseous Fuel Ratio :1	Engine Speed rpm	LFE ΔP "h2O	Intake Manif Press psia	Baro Press psia	JP-8 Fuel Flow lb/hr	Gaseous Fuel Flow lb/hr	Torque ft·lb	Exhaust HC ppm	Intake HC ppm	Dew Point °F	LFE Air Density lb/ft³
146	4 Nov 02	12:45:59	20-06-27-96.7	75.4	46.3	96.8	94.6	79.2	81.8	182.0	73.5	137.0	524.8	487.8	22.6	0.445	40.56	10.07	51.6	408.35	411.00	78.63	96.26	83.78	2001.3	1.785	14.02	14.26	5.194	4.874	59.4	2543	27254	56.8	0.071
147	4 Nov 02	12:53:27	20-08-27-96.6	75.7	45.8	99.5	96.7	84.3	87.6	192.5	78.1	154.4	661.8	630.8	30.5	0.408	32.76	12.44	60.7	407.36	409.04	54.01	96.59	83.25	2002.2	1.805	14.01	14.25	7.543	4.893	79.9	2091	26907	53.3	0.071
148	4 Nov 02	13:10:46	20-10-29-96.6	75.8	46.2	100.9	101.5	85.6	94.5	210.3	75.4	169.9	817.2	777.8	38.3	0.386	27.51	14.78	66.5	406.61	408.26	41.39	96.73	82.03	2002.1	1.811	14.00	14.24	9.825	4.957	100.4	1678	29377	53.3	0.070
149	4 Nov 02	13:33:51	20-12-30-96.6	77.3	44.3	110.0	110.2	96.3	100.9	222.5	85.0	188.5	979.5	920.8	45.6	0.387	22.12	17.67	69.2	390.91	392.53	31.98	94.80	71.74	2001.3	1.798	14.02	14.24	12.225	5.449	119.8	1638	30082	53.6	0.069
150	4 Nov 02	13:37:57	20-12-00-96.7	77.1	44.1	112.5	109.7	96.9	103.4	227.8	87.3	196.8	1096.5	1023.3	45.5	0.413	20.85	18.76	100.0	391.19	392.76	20.85	94.97	-	2001.8	1.803	14.02	14.24	18.762	-0.359	119.3	750	36	53.9	0.069
151	4 Nov 02	13:42:17	20-10-00-96.7	77.2	43.6	114.0	108.6	97.0	103.7	230.6	87.5	185.7	888.4	857.5	37.7	0.399	25.96	15.02	99.1	389.90	391.44	26.20	94.66	-	2003.0	1.797	14.03	14.24	14.880	0.139	98.8	766	33	53.5	0.069
152	4 Nov 02	13:46:53	20-08-00-96.6	76.9	43.9	115.2	108.7	96.2	102.5	229.2	86.2	173.5	726.7	708.4	30.3	0.412	31.18	12.48	98.2	389.26	390.77	31.75	94.38	-	2005.3	1.790	14.02	14.24	12.262	0.222	79.3	751	52	53.3	0.069
153	4 Nov 02	13:55:22	20-06-00-96.6	77.0	44.1	114.6	108.0	89.9	97.4	221.5	83.6	159.8	587.7	567.3	23.0	0.450	37.72	10.34	97.0	389.91	391.42	38.01	93.47	-	2001.0	1.759	14.01	14.24	10.022	0.314	60.3	718	25	53.2	0.070
154	4 Nov 02	14:09:48	15-06-28-97.1	76.8	43.8	108.4	105.4	86.6	92.8	205.3	78.1	157.3	526.2	504.2	17.7	0.451	38.08	7.98	54.8	303.76	304.95	69.44	72.40	84.32	1550.9	1.356	14.09	14.23	4.374	3.603	59.9	1986	27965	53.5	0.070
155	4 Nov 02	14:17:56	15-08-29-97.2	76.8	43.8	107.0	107.1	86.9	95.2	204.7	80.6	173.7	719.5	673.2	23.4	0.466	27.80	10.89	65.0	302.72	303.89	42.78	72.20	79.37	1551.2	1.353	14.09	14.23	7.076	3.814	79.1	1852	28789	53.1	0.070
156	4 Nov 02	14:23:02	15-10-30-97.2	77.2	43.9	107.2	108.6	88.3	97.5	208.6	81.0	186.0	826.8	780.0	29.6	0.417	24.74	12.36	68.0	305.73	306.91	36.38	73.10	77.30	1551.7	1.372	14.09	14.23	8.404	3.955	100.3	1650	29791	53.1	0.070
157	4 Nov 02	14:29:47	15-12-30-97.2	77.1	43.8	107.9	109.7	92.5	101.1	218.2	83.4	203.3	1009.1	927.7	35.4	0.422	20.13	14.96	73.5	301.16	302.34	27.38	72.56	75.98	1551.4	1.369	14.10	14.23	10.999	3.963	119.9	1304	29881	53.5	0.069
158	4 Nov 02	14:33:03	15-12-00-97.2	77.1	43.7	107.5	108.7	105.8	106.0	220.4	71.9	204.3	1130.3	1012.8	35.6	0.460	18.42	16.39	99.3	301.97	303.14	18.50	74.49	-	1553.1	1.428	14.10	14.24	16.324	0.069	120.5	626	58	53.4	0.068
159	4 Nov 02	14:39:07	15-10-00-97.1	77.2	44.1	105.5	108.8	107.0	107.1	221.1	70.9	188.0	907.2	854.7	29.4	0.432	23.88	12.73	99.3	304.00	305.18	24.05	75.18	-	1551.6	1.443	14.09	14.23	12.639	0.091	99.7	92	52	53.6	0.068
160	4 Nov 02	14:46:40	15-08-00-97.1	77.3	44.0	103.8	108.1	103.6	104.0	214.5	69.4	171.4	739.3	695.2	23.5	0.448	29.21	10.50	99.3	306.73	307.95	29.42	75.42	-	1554.0	1.442	14.09	14.23	10.427	0.073	79.3	63	39	53.6	0.070
161	4 Nov 02	14:51:49	15-06-00-97.1	77.3	43.5	101.1	105.9	90.8	98.8	209.0	78.2	158.9	549.9	538.1	17.8	0.447	38.98	7.95	96.6	309.70	310.92	40.35	74.42	-	1550.3	1.401	14.09	14.23	7.675	0.271	60.2	78	20	53.7	0.070

Throttling Tests

Run #	Date (d mmm yy)	Time (h:mm:ss)	Test Comment	Temp-RH °F	Relative Humidity %	JP-8 Fuel In °F	Pentane Fuel In °F	Inlet Air (LFE) °F	Intake Manifold Air °F	Oil Sump °F	Engine Cooling Air In °F	Engine Cooling Air Out °F	Exhaust Cylinder #1 °F	Exhaust Stack °F	Engine Power bhp	BSFC lb/bhp·hr	A/F Ratio LFE Total :1	Total Fuel Flow lb/hr	% Pilot JP-8 %	Air Flow LFE Dry lb/hr	Air Flow LFE Wet lb/hr	A/F Ratio LFE JP-8 only :1	Air Flow LFE acfm	Air/Gaseous Fuel Ratio :1	Engine Speed rpm	LFE ΔP "h2O	Intake Manif Press psia	Baro Press psia	JP-8 Fuel Flow lb/hr	Gaseous Fuel Flow lb/hr	Torque ft·lb	Exhaust HC ppm	Intake HC ppm	Dew Point °F	LFE Air Density lb/ft³
162	6 Nov 02	13:50:29	15-06-00-98.3	73.0	27.8	85.4	78.0	82.6	83.5	143.1	78.1	138.3	505.4	478.8	17.6	0.480	39.00	8.48	88.4	330.58	331.84	44.09	77.20	-	1548.6	1.438	14.26	14.42	7.497	0.980	59.8	581	42	53.4	0.072
163	6 Nov 02	14:08:27	20-12-00-97.7	73.4	26	102.4	98.4	96.5	103.8	207.9	83.6	191.2	1084.3	1024.2	45.7	0.405	22.01	18.54	100.0	408.04	408.59	22.01	97.40	-	1999.9	1.852	14.17	14.41	18.540	-0.634	120.1	677	71	37.8	0.070
164	6 Nov 02	14:18:03	20-06-00-97.7	73.5	25.9	105.0	99.1	85.2	94.8	211.2	77.5	154.3	575.3	562.4	23.0	0.431	41.18	9.91	100.0	408.10	408.59	41.18	95.42	-	2001.0	1.712	13.95	14.41	9.888	0.392	60.0	718	44	36.4	0.071
165	6 Nov 02	14:32:17	20-06-00-96.2	73.3	25.6	103.6	96.0	84.6	92.2	205.8	78.0	151.7	569.7	548.1	22.9	0.449	38.11	10.28	96.2	391.72	392.19	39.62	91.50	-	2001.3	1.712	13.95	14.41	9.910	-0.734	60.5	670	46	36.4	0.071
166	6 Nov 02	14:40:06	20-12-00-96.2	73.6	25.5	104.4	98.0	95.9	99.5	209.4	82.4	186.6	1078.0	994.5	45.7	0.429	19.76	19.60	95.1	387.24	387.68	20.78	92.34	-	1998.3	1.753	13.96	14.41	18.631	0.969	120.2	750	49	35.9	0.070
167	6 Nov 02	14:46:06	20-10-00-96.2	74.0	25.2	106.8	102.2	96.1	102.4	216.6	81.2	179.1	873.1	835.8	37.9	0.394	25.91	14.91	99.6	386.39	386.83	26.01	92.17	-	2002.2	1.751	13.96	14.41	14.858	0.052	99.3	762	48	36.1	0.070
168	6 Nov 02	14:51:11	20-08-00-96.3	73.8	25.5	107.6	103.2	91.9	100.2	217.3	81.2	168.7	714.3	691.7	30.4	0.398	31.78	12.12	100.0	385.32	385.76	31.78	91.22	-	1996.7	1.723	13.96	14.41	12.123	-0.761	80.0	744	37	36.1	0.070
169	6 Nov 02	14:56:03	20-06-00-96.2	74.1	25.1	107.6	102.3	89.0	97.4	214.9	79.9	158.0	585.5	573.6	22.8	0.430	39.25	9.83	100.0	385.66	386.11	39.25	90.82	-	2000.2	1.709	13.96	14.41	9.826	-0.562	59.9	720	40	36.3	0.071
170	6 Nov 02	15:02:22	20-06-16-96.2	74.1	24.7	106.9	99.3	86.0	94.3	211.4	78.2	153.4	577.7	557.3	23.1	0.408	38.26	10.11	79.6	386.74	387.18	48.06	90.57	187.48	2000.6	1.697	13.96	14.41	8.047	2.063	60.6	1649	15603	36.1	0.071
171	6 Nov 02	15:06:17	20-06-32-96.1	74.2	24.7	106.1	99.4	85.4	93.4	208.8	78.9	151.9	563.6	543.7	23.1	0.443	38.05	10.22	58.0	388.81	389.24	65.64	90.96	90.52	1998.2	1.703	13.94	14.40	5.923	4.295	60.6	2164	31606	35.7	0.071
172	6 Nov 02	15:15:59	20-08-30-96.2	74.5	25.1	105.3	103.2	89.0	95.1	206.5	80.0	159.6	676.3	637.1	30.4	0.404	31.68	12.30	65.5	389.66	390.09	48.41	91.78	91.71	1997.6	1.727	13.95	14.40	8.050	4.249	80.0	1914	29814	35.8	0.070
173	6 Nov 02	15:20:48	20-08-16-96.2	74.4	25.2	105.6	102.8	89.8	96.5	207.4	80.4	162.4	695.5	656.7	30.7	0.404	31.27	12.42	81.9	388.32	388.77	38.20	91.60	172.28	2001.1	1.726	13.95	14.40	10.166	2.254	80.6	1385	16222	36.5	0.070
174	6 Nov 02	15:28:06	20-10-16-96.1	74.5	25.5	106.6	103.4	93.2	100.9	211.2	82.3	175.1	850.8	798.6	38.2	0.390	26.29	14.92	85.6	392.35	392.80	30.72	93.12	182.11	2000.9	1.762	13.94	14.40	12.770	2.155	100.4	1277	16283	36.5	0.070
175	6 Nov 02	15:31:49	20-10-31-96.1	74.1	25.7	107.6	105.7	94.5	102.8	214.0	83.2	175.8	829.7	786.6	37.9	0.408	26.72	14.57	71.1	389.35	389.82	37.57	92.64	92.51	2001.8	1.756	13.95	14.40	10.365	4.209	99.5	1692	31296	36.9	0.070
176	6 Nov 02	15:40:03	20-12-16-96.2	74.6	25.2	109.9	110.2	100.2	105.6	221.9	84.9	190.4	1002.1	938.8	45.7	0.385	21.57	17.58	75.5	379.11	379.57	28.55	91.13	88.10	2002.3	1.740	13.95	14.40	13.277	4.303	119.8	1529	31057	36.7	0.069
177	6 Nov 02	15:44:20	20-12-16-96.2	74.6	25.6	111.4	110.5	103.2	106.9	226.7	87.1	196.5	1064.0	995.2	46.0	0.398	20.58	18.30	88.6	376.62	377.06	23.21	91.02	181.26	2001.5	1.744	13.95	14.40	16.227	2.078	120.7	1165	15824	36.6	0.069
178	6 Nov 02	15:51:27	15-06-00-97.3	73.3	24.7	110.9	107.8	91.6	103.2	222.9	84.7	170.2	574.0	570.0	17.8	0.457	36.38	8.11	98.7	294.99	295.34	36.87	69.83	-	1549.4	1.318	14.12	14.40	8.002	0.107	60.2	646	38	37.0	0.070
179	6 Nov 02	15:57:54	15-06-14-97.3	73.5	24.6	108.1	104.9	87.7	99.0	214.6	84.2	164.3	561.4	542.2	17.7	0.451	37.33	7.98	85.2	297.93	298.25	43.82	70.01	252.04	1549.6	1.314	14.11	14.40	6.799	1.182	60.0	1264	13639	35.0	0.071
180	6 Nov 02	16:02:06	15-06-32-97.3	73.9	24.1	106.6	103.8	86.4	97.5	209.3	83.4	162.2	548.7	532.1	17.8	0.464	36.37	8.25	63.7	299.96	300.28	57.11	70.33	100.20	1549.5	1.318	14.11	14.40	5.253	2.994	60.2	1761	31744	35.1	0.071
181	6 Nov 02	16:05:57	15-06-00-97.2	73.7	24.2	105.5	102.7	85.9	96.4	204.7	83.2	161.5	559.2	534.4	17.9	0.447	36.67	8.26	94.5	302.99	303.30	38.82	70.97	-	1554.4	1.329	14.10	14.40	7.805	0.458	60.6	655	48	34.9	0.071
182	8 Nov 02	11:53:11	15-06-00-96.6	74.1	45.7	97.4	90.2	88.1	91.2	177.0	78.9	149.9	538.6	511.7	17.7	0.441	2.70	7.81	100.0	300.33	300.64	38.46	71.13	-	1547.6	1.336	14.01	14.30	7.810	-0.132	60.1	569	17	34.9	0.070
183	8 Nov 02	12:09:18	15-08-00-96.5	74.4	45.4	102.9	96.9	94.6	97.9	192.7	82.5	167.4	686.1	645.7	23.6	0.423	2.03	9.98	98.0	294.20	295.32	30.08	70.86	-	1549.6	1.341	14.00	14.29	9.782	0.196	79.9	578	25	51.8	0.069
184	8 Nov 02	12:17:40	15-10-00-96.4	74.3	45.2	101.6	99.2	87.8	100.3	198.9	81.5	182.4	870.5	810.3	29.5	0.418	1.70	12.31	100.0	301.02	302.15	24.46	71.62	-	1550.9	1.343	13.99	14.29	12.307	-0.107	99.8	601	29	51.7	0.070
185	8 Nov 02	12:25:04	15-12-00-96.5	74.4	45.0	101.8	101.2	91.7	102.8	204.7	83.3	202.6	1103.0	1008.4	35.4	0.469	1.24	16.60	94.1	298.78	299.90	19.11	71.61	-	1548.9	1.350	13.99	14.28	15.631	0.972	120.1	572	13	51.7	0.070
186	8 Nov 02	12:31:07	15-12-14-96.5	74.6	45.5	103.7	101.2	93.7	107.7	215.8	85.0	210.2	1090.2	1021.7	35.5	0.443	1.27	15.70	85.1	293.10	294.23	21.94	70.51	125.20	1551.0	1.332	14.00	14.29	13.362	2.341	120.2	748	13860	52.1	0.070
187	8 Nov 02	12:36:49	15-10-16-96.4	74.6	46.0	105.6	106.1	95.9	108.7	221.0	83.2	194.7	861.0	829.3	29.6	0.416	1.62	12.33	79.2	294.59	295.75	30.16	71.17	115.01	1551.0	1.348	13.99	14.28	9.767	2.561	100.3	878	15799	52.4	0.069
188	8 Nov 02	12:50:37	15-08-16-96.4	74.9	47.1	108.2	110.7	98.2	111.3	228.9	86.0	214.6	1065.0	1002.0	35.2	0.438	1.28	15.42	82.8	289.73	290.94	22.69	70.35	109.19	1549.3	1.328	13.98	14.27	12.769	2.653	119.4	794	16069	53.4	0.069
189	8 Nov 02	12:58:33	15-08-16-96.4	74.9	46.0	108.9	110.3	91.5	105.2	225.4	82.8	182.9	716.6	692.3	23.9	0.449	1.85	10.72	74.8	293.83	295.00	36.62	70.48	108.94	1550.4	1.328	13.98	14.27	8.023	2.697	80.8	1011	15939	52.7	0.070
190	8 Nov 02	13:08:05	15-06-14-96.4	75.2	46.7	106.9	107.1	87.1	99.0	214.5	78.5	163.5	548.1	531.2	17.6	0.482	2.31	8.50	69.2	291.57	292.78	49.56	69.41	111.49	1549.5	1.301	13.98	14.26	5.883	2.615	59.7	1202	14239	53.4	0.070
191	8 Nov 02	13:14:16	15-06-30-96.3	75.2	46.8	105.3	106.9	85.8	97.0	207.2	79.0	163.7	521.9	505.9	17.9	0.468	2.30	8.39	36.3	292.90	294.13	96.23	69.59	54.83	1550.6	1.302	13.97	14.27	3.044	5.342	60.7	1728	30116	53.4	0.070
192	8 Nov 02	13:23:10	15-08-28-96.3	75.4	47.4	104.1	107.3	88.4	99.3	207.7	79.5	179.4	717.3	668.7	23.8	0.491	1.68	11.67	53.2	295.02	296.29	47.53	70.44	54.03	1551.0	1.322	13.96	14.26	6.208	5.460	80.4	1589	27500	54.0	0.070
193	8 Nov 02	13:29:28	15-10-27-96.3	75.5	47.1	104.1	108.5	90.2	102.5	211.3	80.1	187.6	770.3	722.9	29.4	0.416	1.61	12.23	55.8	294.23	295.48	43.12	70.49	54.40	1548.2	1.326	13.96	14.26	6.823	5.409	99.8	1517	26725	53.9	0.070
194	8 Nov 02	13:54:11	15-06-30-96.3	75.7	47.4	105.3	110.8	95.7	106.8	220.6	81.5	208.5	957.2	890.9	35.3	0.415	1.32	14.66	63.3	288.88	290.13	31.11	69.92	53.72	1553.4	1.324	13.97	14.26	9.286	5.378	119.4	1045	25842	54.3	0.069
195	8 Nov 02	13:54:24	24-06-00-93.8	75.8	47.4	106.8	99.2	95.4	94.7	207.8	83.2	151.8	621.5	582.8	27.6	0.476	2.38	13.16	94.8	455.33	457.32	36.51	110.20	-	2401.6	2.091	13.61	14.25	12.471	0.685	60.4	526	27	54.3	0.069
196	8 Nov 02	13:59:24	24-06-00-94.6	76.1	47.6	105.7	97.0	83.7	90.5	210.3	79.2	152.7	609.5	587.5	27.5	0.476	2.57	13.09	94.8	484.18	486.36	39.50	116.22	-	2402.0	2.174	13.92	14.25	12.413	0.681	60.2	539	27	54.3	0.071
197	8 Nov 02	14:01:51	24-06-00-95.9	76.1	47.6	105.4	95.7	82.8	89.9	210.6	78.6	152.9	607.8	587.3	27.5	0.476	2.56	13.09	94.6	487.73	489.90	39.38	115.42	-	2401.1	2.156	13.91	14.25	12.386	0.700	60.2	538	25	54.7	0.071
198	13 Nov 02	13:48:29	15-06-00-96.4	73.7	33.5	88.7	80.6	80.9	82.7	152.7	76.4	140.2	499.4	475.3	17.8	0.438	2.64	7.78	95.2	299.02	299.61	40.36	69.43	-	1549.8	1.291	13.98	14.41	7.408	0.376	60.2	632	41	43.2	0.072
201	13 Nov 02	14:48:05	15-08-27-96.3	73.7	33.0	94.5	97.9	81.1	90.9	184.1	73.6	161.5	685.7	634.8	23.5	0.477	1.78	11.20	53.3	299.57	300.16	50.17	69.66	57.33	1550.4	1.296	13.97	14.39	5.971	5.225	79.5	1901	27075	42.5	0.072
202	13 Nov 02	14:54:37	15-08-27-97.2	73.6	32.8	95.4	101.6	83.4	94.3	191.1	73.2	163.8	683.5	639.6	23.6	0.473	1.83	11.17	52.7	307.11	307.69	52.14	71.73	58.20	1549.9	1.338	14.09	14.39	5.890	5.277	79.9	1931	27095	42.5	0.071
203	13 Nov 02	15:00:51	15-06-00-97.1	73.9	32.8	96.0	99.5	84.2	91.7	192.1	70.2	148.3	530.3	506.5	17.8	0.479	2.46	8.50	89.8	305.81	306.40	40.03	71.55	-	1546.3	1.337	14.08	14.39	7.639	0.865	60.4	560	9	42.7	0.071
204	13 Nov 02	15:08:30	24-06-00-94.5	73.5	33.6	96.8	95.0	80.9	87.0	197.0	73.3	142.5	609.8	582.5	27.3	0.481	2.50	13.12	94.1	476.82	477.77	38.63	110.89	-	2400.3	2.066	13.70	14.39	12.344	0.772	59.7	605	25	43.1	0.072
205	13 Nov 02	15:14:13	24-08-00-94.5	73.9	33.5	98.8	92.6	80.4	86.5	203.0	73.7	152.0	741.6	700.2	36.7	0.442	2.02	16.22	95.8	467.82	477.83	30.68	110.31	-	2401.3	2.063	13.71	14.39	15.545	0.679	80.2	661	27	43.4	0.072
206	13 Nov 02	15:19:07	24-10-00-94.6	74.0	33.0	100.6	93.5	85.1	89.7	209.2	74.2	163.7	900.7	846.9	45.8	0.427	1.66	19.54	96.7	472.03	472.96	24.98	110.63	-	2401.4	2.073	13.72	14.39	18.896	0.648	100.2	729	16	43.1	0.071
207	13 Nov 02	15:23:48	24-10-16-94.6	74.1	32.6	102.7	96.1	89.9	93.1	214.9	73.0	166.1	878.8	839.9	45.4	0.415	1.68	18.82	76.3	467.86	468.76	32.59	110.62	104.85	2398.2	2.085	13.72	14.39	14.356	4.462	99.4	1302	15985	42.9	0.070
208	13 Nov 02	15:30:30	24-12-00-94.7	74.1	33.0	104.6	99.7	96.3	97.7	223.1	75.0	182.8	1129.1	1070.5	55.1	0.435	1.33	23.95	96.9	463.17	464.09	19.97	110.81	-	2401.9	2.106	13.73	14.39	23.195	0.753	120.5	591	32	43.1	0.070
209	13 Nov 02	15:36:50	24-12-16-94.7	74.1	32.8	107.2	104.1	94.4	99.5	232.7	75.6	184.0	1073.1	1031.2	54.4	0.415	1.39	22.59	79.9	461.97	462.87	25.60	109.27	62.75	2399.4	2.089	13.73	14.39	18.036	4.553	119.3	868	16193	43.0	0.071
210	13 Nov 02	15:40:54	24-12-26-94.6	74.3	32.5	108.0	108.0	93.2	99.9	238.4	75.0	184.4	1027.5	991.1	54.6	0.405	1.40	22.11	66.9	459.18	460.06	31.04	109.27	62.75	2401.3	2.069	13.72	14.38	14.792	7.318	119.3	1010	26347	42.9	0.070
211	13 Nov 02	15:44:45	24-10-26-94.6	74.2	32.4	110.1	110.9	94.8	99.4	238.4	75.0	174.6	869.8	849.4	45.6	0.408	1.64	18.63	60.8	457.40	458.27	40.39	109.17	62.64	2400.7	2.071	13.72	14.38	11.324	7.303	99.8	1109	26153	42.8	0.070
212	13 Nov 02	15:52:11	24-10-16-94.6	74.1	32.5	110.1	110.9	93.8	98.6	232.7	75.1	174.5	899.1	863.5	45.5	0.422	1.61	19.24	75.8	454.86	455.73	33.41	108.55	98.52	2400.2	2.069	13.72	14.38	14.590	4.651	99.7	1339	16162	42.7	0.070
213	13 Nov 02	15:58:26	24-08-16-94.6	74.0	32.6	110.7	109.7	95.4	97.8	233.5	74.9	163.0	756.8	729.2	36.8	0.444	1.88	16.33	71.7	454.86	455.73	38.88	108.72	98.27	2399.1	2.064	13.72	14.38	11.699	4.629	80.5	1526	16227	42.7	0.070
214	13 Nov 02	16:02:46	24-08-28-94.5	74.1	32.6	110.1	111.3	95.3	96.8	230.6	75.4	161.4	730.9	704.2	36.7	0.438	1.88	16.08	51.6	454.86	455.73	58.36	108.72	58.36	2397.3	2.060	13.71	14.38	8.293	7.784	80.3	1781	27689	42.9	0.070
215	13 Nov 02	16:07:08	24-06-28-94.5	74.1	33.1	108.4	112.2	93.9	95.7	227.4	73.9	152.8	603.0	591.2	27.4	0.490	2.24	13.43	40.6	455.77	456.67	83.70	108.66	57.11	2401.9	2.059	13.71	14.38	5.445	7.981	59.9	2473	27810	43.2	0.071
216	13 Nov 02	16:11:17	24-06-16-94.5	74.3	33.1	107.1	109.4	89.6	93.6	223.3	72.0	149.1	619.9	596.6	27.5	0.495	2.29	13.60	66.5	462.44	463.36	51.11	109.39	101.52	2400.7	2.061	13.70	14.38	9.048	4.555	60.2	1815	15716	43.4	0.071

Run #	Date (d mmm yy)	Time (h:mm:ss)	Test Comment	Temp-RH °F	Relative Humidity %	JP-8 Fuel In °F	Pentane Fuel In °F	Inlet Air (LFE) °F	Intake Manifold Air °F	Oil Sump °F	Engine Cooling Air In °F	Engine Cooling Air Out °F	Exhaust Cylinder #1 °F	Exhaust Stack °F	Engine Power bhp	BSFC lb/bhp·hr	A/F Ratio LFE Total :1	Total Fuel Flow lb/hr	% Pilot JP-8 %	Air Flow LFE Dry lb/hr	Air Flow LFE Wet lb/hr	A/F Ratio LFE JP-8 only :1	Air Flow LFE acfm	Air / Gaseous Fuel Ratio :1	Engine Speed rpm	LFE ΔP "h2O	Intake Manif Press psia	Baro Press psia	JP-8 Fuel Flow lb/hr	Gaseous Fuel Flow lb/hr	Torque ft·lb	Exhaust HC ppm	Intake HC ppm	Dew Point °F	LFE Air Density lb/ft³
217	14 Nov 02	16:26:23	15-06-00-94.3	77.5	50.5	102.4	99.2	84.1	95.3	197.6	81.7	159.4	551.2	536.8	17.7	0.476	2.24	8.46	90.9	276.70	278.16	35.99	65.85	-	1550.0	1.228	13.68	14.22	7.688	0.768	60.1	574	2	57.6	0.070
218	14 Nov 02	16:31:01	15-06-30-94.3	77.7	50.7	102.5	97.1	83.8	94.5	196.8	81.9	158.3	516.1	506.7	17.7	0.450	2.27	7.95	35.0	274.20	275.67	98.58	65.24	53.04	1547.3	1.217	13.68	14.22	2.781	5.170	60.0	2331	29776	57.9	0.070
219	14 Nov 02	16:38:04	15-08-30-94.3	77.9	50.7	102.9	102.7	84.8	96.6	199.6	82.3	172.3	680.3	635.9	23.5	0.465	1.69	10.93	46.7	278.63	280.13	54.58	66.41	47.83	1548.7	1.240	13.68	14.22	5.105	5.826	79.7	1931	29579	58.1	0.070
220	14 Nov 02	16:41:46	15-08-00-94.4	77.7	50.9	103.1	102.2	85.7	98.3	202.5	82.7	176.9	760.1	701.0	23.5	0.485	1.70	11.37	92.4	281.09	282.60	26.76	67.11	-	1549.7	1.254	13.68	14.22	10.504	0.866	79.5	682	1	58.1	0.070
221	14 Nov 02	16:50:36	15-10-00-94.4	77.7	50.6	103.5	102.5	91.7	102.3	208.9	86.8	184.9	899.7	843.0	29.6	0.454	1.44	13.42	92.4	281.75	283.25	22.73	68.03	-	1549.9	1.281	13.69	14.22	12.396	1.022	100.2	633	2	57.9	0.069
222	14 Nov 02	16:54:25	15-10-28-94.4	77.3	51.0	104.2	103.8	94.0	104.9	209.4	88.1	184.3	816.0	780.2	29.6	0.271	2.48	8.03	100.0	283.11	284.62	35.26	68.64	-	1550.5	1.296	13.69	14.22	8.029	-0.152	100.2	1509	28361	57.7	0.069
223	14 Nov 02	17:01:41	15-12-32-94.4	77.4	50.9	105.5	107.1	99.1	109.2	215.2	85.5	197.7	975.7	909.2	35.3	0.491	1.09	17.34	59.5	281.70	283.20	27.32	68.93	40.10	1551.8	1.309	13.69	14.21	10.311	7.024	119.6	1159	31506	57.8	0.068
224	18 Nov 02	14:25:31	15-12-00-94.3	76.1	42.5	105.1	104.7	101.7	104.6	209.8	79.2	195.8	1029.9	950.6	35.3	0.430	1.19	15.18	94.1	263.28	264.20	18.44	63.94	-	1548.8	1.220	13.67	14.35	14.280	0.902	119.6	357	-136	51.6	0.069
225	18 Nov 02	14:40:15	15-12-00-90.9	75.5	42.3	108.5	105.6	92.7	107.3	225.3	84.3	208.0	1112.4	1016.2	35.7	0.424	1.12	15.10	100.0	243.55	244.38	16.12	58.20	-	1552.0	1.099	13.18	14.35	15.105	-0.082	120.7	30	-8	51.0	0.070
226	18 Nov 02	15:00:36	15-06-00-89.7	75.7	42.8	104.3	94.7	84.2	91.9	203.7	83.7	158.2	565.3	536.6	17.8	0.440	2.11	7.82	100.0	234.90	235.72	30.03	55.28	-	1552.6	1.033	13.02	14.34	7.822	-0.148	60.2	588	181	51.5	0.071
227	18 Nov 02	15:05:25	15-06-00-86.5	75.7	42.8	103.3	92.9	83.6	90.8	199.9	82.7	157.4	583.1	548.2	17.9	0.440	1.88	7.88	100.0	213.01	213.76	27.04	50.08	-	1554.7	0.936	12.54	14.34	7.877	-0.060	60.4	604	128	51.5	0.071
228	18 Nov 02	15:18:54	15-06-00-82.8	76.3	42.4	101.6	90.4	83.0	89.7	195.2	82.6	157.3	590.1	555.8	17.7	0.432	1.75	7.65	100.0	191.62	192.29	25.03	44.99	-	1551.5	0.841	12.01	14.34	7.654	-0.091	60.0	635	89	51.8	0.071
229	18 Nov 02	15:26:03	15-06-00-79.2	76.6	42.4	100.4	87.4	80.3	86.9	192.0	79.8	156.2	603.4	568.7	17.7	0.438	1.54	7.77	100.0	170.45	171.06	21.94	39.83	-	1552.7	0.743	11.49	14.35	7.770	-0.145	60.0	658	136	52.0	0.072
230	18 Nov 02	15:33:49	15-06-00-75.9	76.2	42.5	99.1	85.0	79.5	85.3	191.2	78.1	155.9	622.5	582.9	17.7	0.440	1.36	7.80	100.0	151.97	152.50	19.49	35.45	-	1553.0	0.662	11.01	14.35	7.795	-0.093	60.0	679	170	51.7	0.072
231	18 Nov 02	15:41:19	15-06-00-71.7	76.3	42.6	98.8	84.2	79.5	85.3	190.5	78.8	157.8	654.9	606.5	17.6	0.444	1.14	7.82	100.0	127.66	128.11	16.32	29.78	-	1550.7	0.557	10.40	14.35	7.820	-0.110	59.7	708	198	51.9	0.072
232	22 Nov 02	15:31:06	15-06-00-97.9	75.6	29.7	94.8	90.6	89.4	89.3	168.9	74.3	142.3	528.0	494.5	18.0	0.435	2.73	7.83	98.5	310.43	310.95	40.24	73.26	-	1539.7	1.379	14.20	14.40	7.714	0.120	61.4	601	81	41.7	0.071
233	22 Nov 02	15:40:12	15-06-15-97.9	75.8	28.7	97.3	95.5	91.1	91.3	176.1	75.1	143.6	511.5	486.8	17.7	0.438	2.67	7.76	60.9	309.67	310.16	65.46	73.30	102.17	1551.3	1.382	14.19	14.40	4.731	3.031	60.0	1720	15093	41.0	0.071
234	22 Nov 02	15:48:36	15-06-15-96.3	76.6	28.6	98.8	103.3	90.2	91.8	178.1	76.4	144.8	519.5	490.3	17.8	0.431	2.53	7.65	61.5	289.04	289.50	61.45	68.30	98.04	1551.4	1.287	13.97	14.40	4.704	2.948	60.1	1709	14580	41.6	0.071
235	22 Nov 02	15:54:38	15-06-14-93.1	76.4	28.2	99.4	105.6	91.3	92.3	179.9	75.7	145.9	535.3	505.1	17.8	0.429	2.30	7.64	62.0	262.48	262.89	55.45	62.15	90.33	1550.4	1.173	13.51	14.40	4.734	2.906	60.3	1727	14281	41.1	0.071
236	22 Nov 02	16:01:46	15-06-14-89.6	76.9	28.3	99.9	107.0	92.0	92.0	181.6	75.7	147.0	551.6	519.6	17.9	0.425	2.02	7.59	62.4	229.05	229.41	48.36	54.30	80.20	1549.3	1.026	13.00	14.40	4.736	2.856	60.5	1744	13743	41.6	0.070
237	22 Nov 02	16:07:52	15-06-13-86.2	77.1	28.3	100.8	107.8	91.5	91.8	184.1	76.3	148.3	559.4	529.8	18.0	0.419	1.86	7.52	61.5	208.32	208.65	45.00	49.35	72.01	1549.8	0.932	12.50	14.40	4.629	2.893	60.9	1796	13409	41.7	0.070
238	22 Nov 02	16:14:23	15-06-13-82.9	76.6	28.2	101.1	108.3	91.1	91.1	185.3	76.1	148.4	567.0	536.1	17.8	0.437	1.70	7.34	61.7	185.72	186.01	41.03	43.96	65.98	1551.3	0.831	12.02	14.40	4.526	2.815	60.4	1831	13059	41.2	0.071
239	22 Nov 02	16:19:58	15-06-11-79.4	77.8	27.9	101.3	108.8	90.7	91.2	185.4	76.0	149.2	583.2	551.3	17.7	0.413	1.50	7.31	61.6	163.46	163.72	36.31	38.67	58.18	1551.2	0.732	11.51	14.40	4.502	2.809	59.9	1878	11399	42.0	0.071
240	22 Nov 02	16:25:22	15-06-10-75.4	77.6	27.9	101.6	109.2	90.7	90.8	186.0	75.7	149.9	607.2	567.3	17.6	0.415	1.27	7.30	61.4	138.55	138.77	30.92	32.78	49.10	1550.4	0.622	10.93	14.40	4.481	2.822	59.6	1878	10090	41.8	0.070
241	22 Nov 02	16:32:22	15-06-09-72.5	76.4	32.4	101.6	109.6	92.0	90.7	187.3	75.6	152.0	638.3	593.9	17.7	0.421	1.11	7.45	62.0	123.57	123.82	26.74	29.32	43.65	1550.6	0.558	10.51	14.40	4.621	2.831	60.0	1844	9173	44.7	0.070
242	25 Nov 02	14:18:10	15-06-30-97.6	70.3	37.6	88.4	103.2	82.1	83.4	160.7	67.4	132.9	463.7	440.4	17.4	0.445	2.61	7.76	22.3	311.15	311.86	179.71	72.66	51.65	1547.8	1.353	14.16	14.37	1.731	6.025	59.1	2680	30052	43.2	0.072
243	25 Nov 02	14:23:48	15-06-28-96.5	70.4	37.5	90.8	106.3	82.8	84.8	166.7	73.7	137.2	482.1	454.7	17.6	0.454	2.40	8.01	25.6	294.02	294.68	143.43	68.76	49.33	1552.9	1.282	14.00	14.37	2.050	5.960	59.6	2692	27906	43.2	0.071
244	25 Nov 02	14:29:17	15-06-25-93.1	70.4	37.7	96.6	109.5	87.4	93.0	174.7	82.0	149.9	498.9	478.6	17.6	0.436	2.23	7.65	23.3	261.97	262.56	146.73	61.78	44.65	1547.9	1.159	13.51	14.37	1.785	5.868	59.6	2608	24856	43.4	0.071
245	25 Nov 02	14:34:03	15-06-26-89.7	70.5	37.2	96.6	111.2	85.6	88.3	177.3	69.4	141.2	504.9	481.2	17.6	0.451	1.89	7.93	26.1	228.99	229.50	110.71	53.82	39.08	1547.5	1.008	13.01	14.37	2.068	5.859	59.7	2762	25875	43.1	0.071
246	25 Nov 02	14:42:38	15-06-22-86.2	70.5	37.3	99.2	112.6	87.2	91.8	181.0	75.8	144.9	518.5	493.1	17.6	0.433	1.77	7.64	22.7	207.40	207.87	119.60	48.89	35.15	1549.8	0.918	12.50	14.37	1.734	5.901	59.7	2993	21686	43.2	0.070
247	25 Nov 02	14:53:19	15-06-29-79.3	70.7	38.3	103.4	116.1	91.5	96.8	190.3	74.8	157.6	578.7	546.9	17.8	0.434	1.32	7.74	23.3	156.93	157.30	87.26	37.29	26.43	1547.4	0.706	11.50	14.37	1.798	5.937	60.5	3035	28674	44.0	0.070
248	25 Nov 02	14:59:07	15-06-37-97.6	70.7	37.9	102.0	116.6	87.8	91.5	191.8	70.8	147.0	488.3	476.8	17.6	0.459	2.46	8.09	27.2	305.06	305.77	138.57	72.01	51.78	1552.5	1.351	14.16	14.37	2.201	5.892	59.6	2626	37422	43.8	0.070
249	25 Nov 02	15:05:08	15-12-15-97.6	70.7	38.0	105.0	107.3	90.3	93.4	194.8	72.0	176.5	939.5	851.5	35.8	0.348	1.69	12.46	96.0	305.29	306.00	25.52	72.40	619.07	1549.0	1.363	14.16	14.37	11.964	0.493	121.5	979	15422	43.8	0.070
250	25 Nov 02	15:08:53	15-12-15-96.4	70.8	38.1	101.1	106.7	90.9	95.5	200.5	72.6	180.6	937.6	863.8	35.4	0.398	1.40	14.08	82.5	289.96	290.64	24.96	68.84	117.53	1551.7	1.297	13.99	14.37	11.617	2.467	119.8	940	14811	44.0	0.070
251	25 Nov 02	15:12:57	15-12-16-93.1	70.7	38.5	102.4	107.3	92.9	96.8	204.5	75.1	183.7	961.2	882.9	35.0	0.398	1.20	14.34	82.5	253.03	253.63	21.81	60.29	92.41	1546.8	1.140	13.50	14.37	11.600	2.738	118.5	924	15688	44.2	0.070
252	25 Nov 02	15:16:15	15-12-16-93.1	70.7	38.5	102.4	107.3	92.9	96.8	204.5	75.1	183.7	961.2	882.9	35.0	0.398	1.20	14.34	82.5	253.03	253.63	21.81	60.29	92.41	1546.8	1.140	13.50	14.37	11.600	2.738	118.5	924	15688	44.2	0.070
253	25 Nov 02	15:18:21	15-12-15-93.1	70.8	38.5	102.5	107.6	92.1	97.0	206.5	73.9	184.3	967.2	888.9	35.3	0.392	1.25	13.81	83.3	253.79	254.40	22.06	60.39	110.03	1546.8	1.140	13.51	14.37	11.505	2.306	119.7	610	15038	44.2	0.070
254	25 Nov 02	15:23:12	15-12-15-93.1	70.8	38.2	103.6	108.7	91.6	97.3	211.5	75.5	191.5	1033.3	953.3	35.3	0.399	1.04	14.62	83.0	223.75	224.28	18.44	53.18	90.10	1547.0	1.008	13.01	14.37	12.135	2.483	119.7	62	15038	44.1	0.070
255	25 Nov 02	15:30:48	15-12-15-97.7	70.7	38.2	105.0	110.7	94.6	100.9	215.4	73.4	185.3	939.2	874.6	35.2	0.399	1.47	14.06	82.2	304.22	304.94	26.33	72.73	121.19	1551.4	1.377	14.16	14.37	11.553	2.510	119.3	980	14905	44.0	0.070
256	27 Nov 02	10:48:02	20-06-00-98.0	75.0	15.3	96.7	90.3	80.5	83.5	189.5	69.9	137.0	533.3	508.0	23.0	0.483	2.56	11.11	88.9	415.60	415.78	42.07	95.49	-	1997.8	1.777	14.22	14.52	9.880	1.233	60.5	514	9	24.7	0.073
257	27 Nov 02	10:53:40	20-06-00-96.5	75.5	14.9	96.6	91.0	80.3	83.5	190.7	70.6	138.8	541.7	518.5	22.9	0.469	2.53	10.74	92.0	396.16	396.32	40.09	91.02	-	1998.0	1.693	14.00	14.52	9.882	0.858	60.2	522	9	24.5	0.073
258	27 Nov 02	10:59:38	20-06-00-93.0	75.3	14.9	97.1	91.8	79.9	84.0	191.6	72.0	140.5	556.9	532.2	22.7	0.433	2.55	9.83	100.0	362.86	363.01	36.90	83.29	-	1997.6	1.548	13.49	14.52	9.833	-0.036	59.7	520	9	24.3	0.073
259	27 Nov 02	11:03:44	20-06-00-89.6	75.4	14.9	97.1	92.1	80.8	83.9	192.1	71.4	140.8	574.6	546.2	22.7	0.439	2.31	9.98	98.7	333.92	334.06	33.91	76.80	-	1997.2	1.423	13.00	14.51	9.847	0.128	59.7	531	9	24.4	0.073
260	27 Nov 02	11:08:53	20-06-00-86.3	75.7	15.0	97.2	92.6	80.0	83.7	191.9	71.2	141.8	594.8	565.7	22.7	0.439	2.28	9.97	100.0	311.49	311.63	31.23	71.54	-	1998.3	1.330	12.51	14.51	9.973	-0.498	59.8	530	8	24.8	0.073
261	27 Nov 02	11:13:48	20-06-00-82.8	76.2	14.8	97.2	92.9	80.3	83.9	193.1	72.5	143.3	616.0	583.4	22.8	0.439	2.14	9.96	100.0	282.91	283.02	28.40	65.01	-	1997.1	1.209	12.00	14.51	9.962	-0.784	59.9	538	9	24.8	0.073
262	27 Nov 02	11:28:33	20-06-00-79.3	76.0	14.9	99.2	94.5	81.0	85.3	197.1	71.6	146.4	650.4	618.8	22.9	0.447	1.82	10.23	100.0	251.50	251.61	24.58	57.86	-	2000.7	1.078	11.50	14.52	10.232	-0.643	60.0	557	11	24.9	0.072
263	27 Nov 02	11:36:12	20-06-00-76.0	76.5	14.8	99.7	94.7	81.8	86.0	197.9	72.5	148.0	675.9	639.5	22.8	0.492	1.39	11.22	91.2	227.00	227.10	22.17	52.32	-	1999.9	0.976	11.02	14.51	10.241	0.982	60.0	586	12	25.1	0.072
264	27 Nov 02	11:42:28	20-06-00-72.3	76.0	15.0	100.4	96.0	80.1	86.6	198.3	75.9	151.9	715.7	679.1	22.8	0.484	1.22	11.04	94.5	196.45	196.54	18.85	45.14	-	1998.4	0.841	10.49	14.51	10.424	0.612	59.9	608	12	25.0	0.073
265	27 Nov 02	11:45:51	20-06-00-69.1	76.2	14.9	100.4	96.2	81.2	86.6	199.1	74.7	152.3	748.1	699.7	22.8	0.499	1.02	11.36	92.4	168.74	168.81	16.08	38.85	-	1997.0	0.726	10.02	14.51	10.497	0.864	59.9	608	12	25.0	0.073
266	27 Nov 02	11:58:27	20-06-15-97.8	76.7	14.7	100.5	97.0	80.7	85.7	198.6	72.8	140.4	527.7	507.4	22.7	0.399	3.02	9.06	65.5	407.21	407.39	68.56	93.71	130.37	1999.0	1.745	14.19	14.50	5.940	3.124	59.7	1650	14690	25.1	0.072
267	27 Nov 02	12:01:57	20-06-15-96.3	76.4	14.7	100.4	103.6	82.1	86.4	198.1	71.8	140.0	535.1	511.4	22.8	0.395	2.92	8.98	66.8	389.39	389.56	64.86	89.85	130.66	1999.4	1.668	13.97	14.50	6.003	2.980	59.8	1655	14916	24.8	0.072
268	27 Nov 02	12:06:37	20-06-15-93.0	76.5	14.9	99.7	106.9	81.0	85.6	197.1	71.2	139.9	550.9	525.5	22.8	0.405	2.63	9.23	65.6	361.39	361.55	59.69	83.23	113.67	1999.0	1.550	13.48	14.50	6.055	3.179	59.8	1694	14942	25.2	0.072
269	27 Nov 02	12:11:38	20-06-16-89.7	76.7	14.7	99.4	108.8	81.3	85.5	196.8	73.3	141.2	567.7	539.9	22.9	0.401	2.44	9.18	65.1	333.42	333.56	55.75	76.83	104.16	2000.3	1.431	13.00	14.50	5.980	3.201	60.1	1731	15564	25.1	0.072
270	27 Nov 02	12:17:35	20-06-17-86.1	75.3	15.8	98.7	109.5	80.1	85.1	196.3	70.7	141.1	588.4	560.0	23.0	0.404	2.13	9.30	63.5	295.53	295.67	50.05	67.95	87.09	2002.6	1.263	12.49	14.50	5.904	3.393	60.3	1767	16899	25.7	0.073
271	27 Nov 02	12:22:16	20-06-13-82.5	74.3	16.8	98.9	110.1	78.6	85.4	196.3	74.4	144.0	612.0	581.3	23.1	0.400	1.92	9.26	63.5	264.46	264.59	45.00	60.65	78.22	2002.7	1.126	11.96	14.50	5.877	3.381	60.7	1801	12855	26.4	0.073
272	27 Nov 02	12:27:19	20-06-10-79.4	73.7	17.2	99.2	110.7	77.6	85.3	196.0	74.2	145.3	633.5	603.3	23.2	0.401	1.73	9.28	62.3	239.08	239.21	41.15	54.74	68.31	2003.4	0.975	11.51	14.49	5.776	3.500	60.7	1842	9658	26.5	0.073
273	27 Nov 02	12:33:38	20-06-08-76.0	74.2	17.3	99.6	111.1	78.9	85.9	197.0	73.5	146.1	651.1	617.0	22.9	0.403	1.54	9.23	61.5	212.78	212.89	37.49	48.86	59.89	2003.2	0.908	11.02	14.49	5.676	3.553	60.1	1815	7547	27.0	0.073
274	27 Nov 02	12:38:42	20-06-06-72.3	77.6	14.7	100.1	111.9	82.0	86.9	197.7	72.4	147.7	679.4	642.1	22.9	0.406	1.34	9.29	60.7	185.77	185.85	32.95	42.90	50.92	2004.3	0.802	10.48	14.49	5.638	3.648	60.0	1831	6474	25.8	0.073
275	27 Nov 02	12:43:15	20-06-07-68.9	77.2	14.8	100.4	112.9	81.9	87.6	198.3	75.0	149.9	709.8	665.1	23.0	0.407	1.15	9.35	60.1	159.99	160.06	28.48	36.94	42.88	2003.7	0.692	9.99	14.49	5.617	3.731	60.2	1883	6508	25.6	0.073
276	27 Nov 02	12:48:30	20-06-16-97.7	75.6	16.2	100.3	112.9	78.3	85.4	199.1	74.7	142.0	527.7	519.4	22.7	0.403	2.99	9.13	58.5	408.82	409.02	76.49	93.77	107.88	2000.2	1.740	14.17	14.49	5.344	3.790	59.5	1784	15800	26.5	0.073